

- I. A Continuation of the Study of the
Action of Amines on Camphor-
oxalic Acid.
 - II. The Combustion of Halogen Com-
pounds in the Presence of Copper
Oxide.
 - III. Some Experiments Relating to the
So-called Infusible Diamide of Para-
sulphaminebenzoic Acid.
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DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF
THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY
WITH THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY.

BY

CHARLES J. ROBINSON.

EASTON, PA. :
ESCHENBACH PRINTING COMPANY.
1906.

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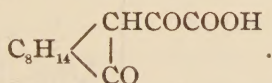
ACKNOWLEDGMENT.

The author takes pleasure in expressing his gratitude to President Remsen, Professor Morse, Professor Jones and Professor Mathews for instruction received from them, and especially to Dr. Tingle, under whose direction this investigation has been pursued, for guidance in the work and for his personal interest. Thanks are also due to Dr. Acree for instruction and for suggestions.

A Continuation of the Study of the Action of Amines on Camphor-oxalic Acid.

INTRODUCTION.

In 1889, J. Bishop Tingle¹ discovered that camphor condenses with ethyl oxalate, in the presence of sodium, the product giving a deep violet-red color with ferric chloride, in alcoholic solution. This is in accord with the work of Claisen and his associates, showing that all ketones, RCOCH_3 , and $\text{RCOCH}_2\text{R}'$, condense, in the presence of sodium, with esters, the latter type of ketone yielding the more stable products. All such condensation compounds obtained by Claisen give color reactions with alcoholic ferric chloride. Subsequent investigation² of the substance formed by the action of ethyl oxalate on camphor showed that it is the ester of an acid, termed *camphoroxalic acid*, which was represented by the formula

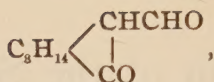


Later, when a general controversy arose as to whether 1,3-diketones are true diketones or unsaturated hydroxy derivatives, a more complete investigation of camphoroxalic acid was undertaken to determine, if possible, whether it has the "keto" or "enol" form, and to study the relative reactivity of the two ketone groups, or the enol and keto groups, the one in the side chain and the other in the ring.

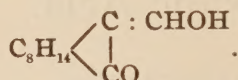
The somewhat analogous compound formed by the action of ethyl formate on camphor, which was at first supposed to have a structure expressed by the formula

¹ Inaug. Diss., Munich, 1889, p. 34.

² J. Chem. Soc., 57, 652 (1890).

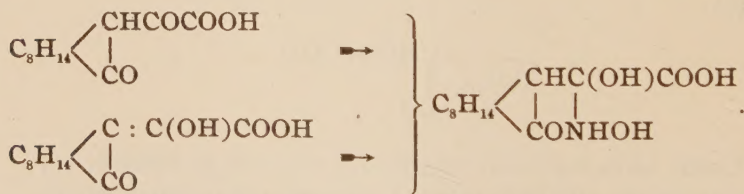


has been thoroughly investigated by Bishop, Claisen and Sinclair,¹ and shown to be

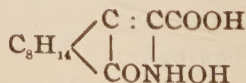


The name oxymethylene camphor was given to the substance by these authors. The work of Bishop Tingle and his associates on camphoroxalic acid² has brought to light facts indicating that it likewise has the unsaturated hydroxy structure, though the evidence cannot be considered conclusive. The chief facts hitherto discovered, which bear on the point, are :

1. The production of a stable addition product with hydroxylamine.³ The stability of the compound is such as to indicate that it is not simply an addition to a carbonyl group. It will be observed that addition to either the diketonic or ketoenolic form would give the same compound, as shown in the formula,



Such a substance might eliminate water in either of two ways, which would result in the formation of the compounds

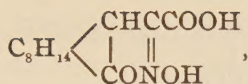


and

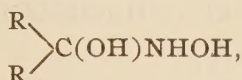
¹ Ann. Chem. (Liebig), **281**, 314.

² Am. Chem. J., **19**, 393 (1897); **20**, 318 (1898); **21**, 248 (1899); **23**, 214 (1900). J. Am. Chem. Soc., **23**, 363 (1901). Am. Chem. J., **34**, 217 (1905).

³ *Ibid.*, **19**, 396, 408.

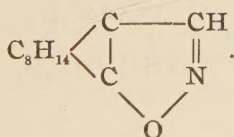


respectively. This latter reaction, however, is simply an expression of the production of an oxime, and it is well known that oxime formation occurs very readily, without its being possible to isolate any intermediate, additive compound, *i. e.*, compounds of the formula



are, in general, highly unstable. The fact that Bishop Tingle's hydroxylamine additive compound was quite stable led him to the conclusion that it resulted from the addition of hydroxylamine to a double linkage in camphoroxalic acid, and, therefore, to regard this acid as being a ketoenolic compound and not a true diketone. This was the first example which had ever been observed of such an addition of hydroxylamine to a double linkage between two carbon atoms. Later, C. Harries¹ and his co-workers found that similar compounds could be obtained from mesityl oxide, phorone, etc.

Attempts to dehydrate the camphoroxalic acid hydroxylamine product led to the elimination of carbon dioxide and 2 molecules of water, and the formation of camphylisoxazole,²

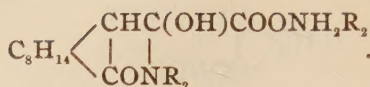


Camphoroxalic acid also forms addition products with diethylamine and dimethylamine³ of the type,

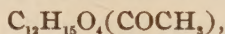
¹ Ber. d. chem. Ges., **30**, 231, 2726.

² Am. Chem. J., **19**, 409.

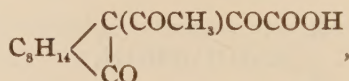
³ *Ibid.*, **34**, 246.



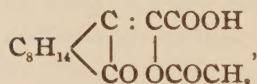
2. With acetic anhydride, a monacetyl derivative,



is produced.¹ This might be either



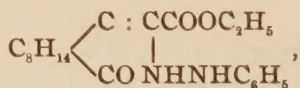
or



but its formation by the direct action of acetic anhydride on camphoroxalic acid makes the latter structure appear more probable.

3. Camphoroxalic acid is hydrolyzed by barium hydroxide to camphor and oxalic acid,² indicating the existence of a double linkage in the side chain.

4. Ethyl camphoroxalate and phenylhydrazine react³ to form what appears to be the hydrazide,



and not the hydrazone,

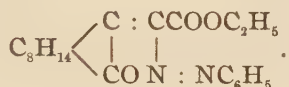


¹ Am. Chem. J., 20, 324.

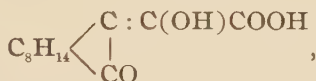
² *Ibid.*, 20, 327.

³ J. Chem. Soc., 57, 655. Am. Chem. J., 19, 402.

because, when it is oxidized by mercuric oxide or hydrogen peroxide, it yields a red, crystalline compound,¹



In view of these facts, the formula

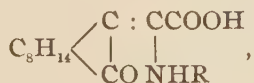


has been tentatively assigned to camphoroxalic acid. The work of Baly and his collaborateurs on the optical properties of enolic and ketonic compounds, of which a review and bibliography has been given recently,² lends a considerable amount of support to the conclusion reached, from purely chemical considerations, by the results described in this dissertation that the point of attack in such compounds is the group C : COH and not CO.

The simple reaction products with primary amines are believed to have the general structure,



when addition products are formed, and



when a molecule of water is eliminated in the reaction.

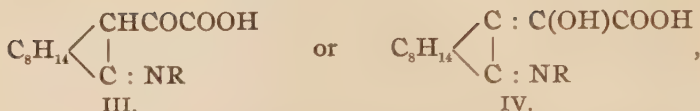
The hypothesis that compounds

¹ Am. Chem. J., **20**, 338; **21**, 258.

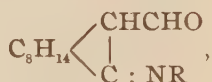
² *Ibid.*, **36**, 213.



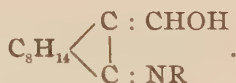
and not



are produced, is supported by the fact that, when heated, the substances in question give up carbon dioxide, forming neutral products. Compounds of the latter type, where carboxyl is joined to —CO— or >C(OH)— , would not be expected to eliminate carbon dioxide; and, if they did, the products would be aldehydes,



or oxymethylene compounds,



The inactivity and neutrality of the substances actually obtained discredit the possibility of such a structure and leave the choice between the first two formulas. For the reasons discussed above, the former of these, I., is preferred.

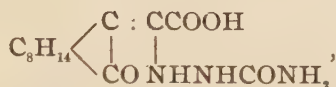
A somewhat extensive investigation of the action of amines, of various types, on camphoroxalic acid has already been made.¹ The present paper contains the results of a continuation of this study. The amines which have been employed are semicarbazine, urea and the methylated ureas, hydrazine, phenylhydrazine and parabromophenylhydrazine. In the course of this investigation, additional evidence indicative of the unsaturated hydroxy structure has been found.

¹ *Vide* Table, Am. Chem. J., **34**, 236.

THEORETICAL.

The Action of Semicarbazine on Camphoroxalic Acid.

In a preliminary experiment on the action of semicarbazine on camphoroxalic acid, J. Bishop Tingle and Alfred Tingle¹ obtained what appeared to be two isomeric derivatives of the formula



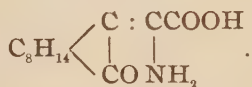
one of which was found to melt at 218° and the other at 209°–210°. The two were separated by the solubility of the former in ether. Subsequently, Bishop Tingle and W. E. Hoffman, Jr.,² obtained, under different conditions, a compound of the same formula which, when crystallized from alcohol, melted at 200°, but when crystallized from glacial acetic acid, melted at 209°–210°. Nothing further was done with these substances at that time. To clear up the apparent discrepancy, I have repeated the two earlier experiments and have compared the products carefully, with the result that the supposedly isomeric substances are proved to be identical. The variation in the melting points recorded in the previous work was found to be due to the exhibition, by the compound, of a remarkable sensitiveness not only to the rate of heating, but also, apparently, to small amounts of impurities. Experiments showing the degree of variation due to differences in the rapidity of the heating are tabulated on page 38, the observed melting point varying from 200°.5, when the rate of heating above 190° was 2° per minute, to 217° when the rate was 15° per minute. The presence of a small amount of resinous matter, not sufficiently large to be detected by analyses, was found to render the substance somewhat soluble in ether, which explains the separation into two portions that was effected by Bishop Tingle and A. Tingle.

The compound was designated in the latter of the two papers mentioned above as “semicarbazine camphoformeneaminecar-

¹ Am. Chem. J., **23**, 224 (1900).

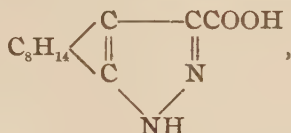
² *Ibid.*, **34**, 251 (1905).

boxylic acid." The name *carbamylcamphoformeneaminecarboxylic acid* seems preferable, as showing more clearly the relation to the simpler compound, *camphoformeneaminecarboxylic acid*,

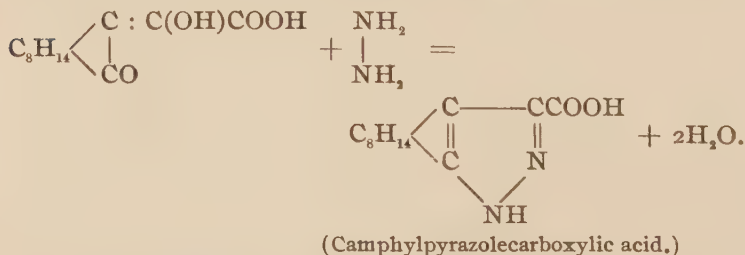


The term "carbamyl" designates satisfactorily the carbamide residue, —NHCONH_2 , which is present.

When camphoroxalic acid and semicarbazine react at 125° , under pressure, the products are hydrazodicarbonamide, $\text{H}_2\text{NCONHNHCONH}_2$, and *camphylpyrazolecarboxylic acid*,

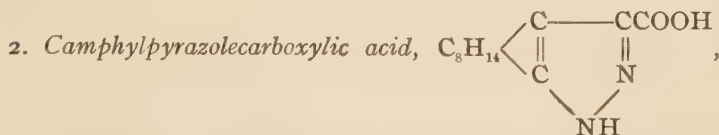


both of which are also products of the fusion of carbamylcamphoformeneaminecarboxylic acid (see below). The formation of these compounds, under the conditions employed, is explained by the fact that semicarbazine breaks down under the influence of heat into hydrazodicarbonamide and hydrazine. The hydrazine then interacts with camphoroxalic acid. The reactions may be expressed thus :



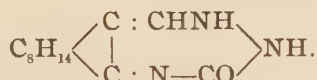
At least three compounds are formed by the fusion of carbamylcamphoformeneaminecarboxylic acid, *viz.* :

1. Hydrazodicarbonamide, $\text{NH}_2\text{CONHNHCONH}_2$, which is insoluble in all the ordinary, neutral, organic solvents, and but slightly soluble in boiling water. It melts at 245° and has been previously obtained from semicarbazine by the elimination of hydrazine.¹ The insoluble compound, melting at 255° , which is mentioned by Bishop Tingle and A. Tingle² as being obtained in small amount, was, no doubt, this same substance. It melts at 245° only when heated very slowly.



The fact that the same compound is obtained by the action of hydrazine on camphoroxalic acid confirms the view that it has the above structure.

3. A compound crystallizing from alcohol in yellow needles, which melt at 305° – 306° . It has the composition of carbamylcamphoformeneaminecarboxylic acid minus the elements of water and carbon dioxide, and is, without doubt, represented by the formula



It may be called *camphyl-3-keto-1,2,4-heptatriazine*.

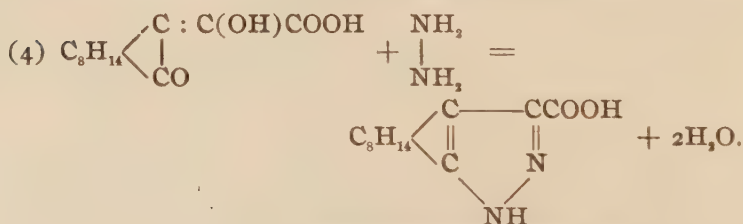
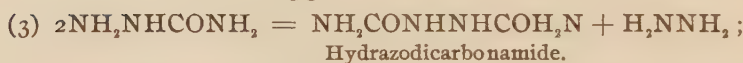
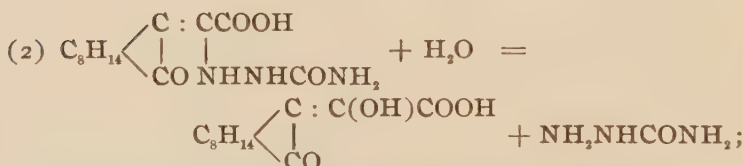
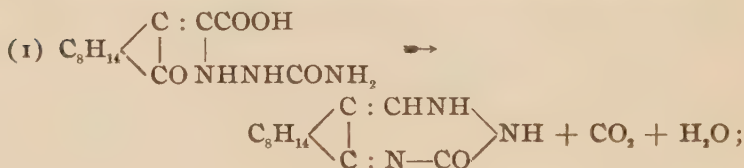
The action of heat on carbamylcamphoformeneaminecarboxylic acid is best explained, I believe, by the following hypothesis: A portion of the compound eliminates water and carbon dioxide and forms the substance melting at 305° – 306° . The water thus formed hydrolyzes another portion of the original substance into its components, semicarbazine and camphoroxalic acid. The reaction then proceeds in the same way as when these two substances are heated together under pressure, hydrazine being formed and condensing with camphoroxalic acid. This condensation involves the elimination of water, which hydrolyzes some of the original compound, and

¹ Thiele: Ann. Chem. (Liebig), **270**, 45. Curtius: Ber. d. chem. Ges., **27**, 57.

² Am. Chem. J., **23**, 228.

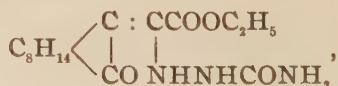
the greater the extent of the hydrolysis the larger the amount of water subsequently formed. With water present, hydrolysis would be expected to take place more readily than condensation to the 7-membered ring compound, camphylketoheptatriazine. This explains the fact that the latter substance was obtained in very small amount.

The following equations express the reactions involved :



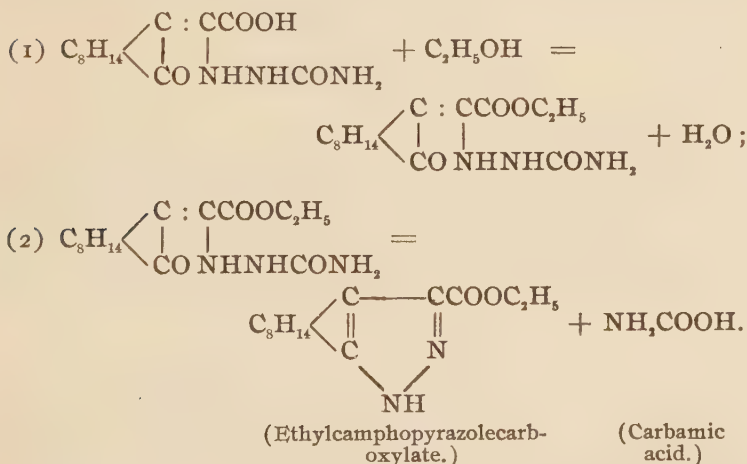
Camphylpyrazolecarboxylic acid.

Experiments were also made on the action of dry hydrogen chloride on carbamylcamphoformeneaminecarboxylic acid, in the presence of absolute alcohol. If the reaction is carried out at about 0° , the primary product is *ethyl carbamylcamphoformeneaminecarboxylate*,



which melts at 191° . The same compound has been described

by Bishop Tingle and A. Tingle,¹ who prepared it by the action of semicarbazine on ethyl camphoroxalate. Their preparation melted at 202°. This difference in melting point is doubtless due to differences in the rapidity of heating, a behavior which is so markedly shown in the case of the acid. When this ester is allowed to stand in the alcoholic hydrochloric acid solution in which it was made it soon decomposes, and ethyl camphylpyrazolecarboxylate is formed, which melts at 91°–92° and crystallizes from ligroin in magnificent, monoclinic, tabular crystals. This ester is strongly basic and forms a stable hydrochloride, that softens at 151° and melts at 156°. Camphylpyrazolecarboxylic acid itself is basic to the extent of dissolving in dilute, aqueous acids, though nearly insoluble in water. The action of hydrochloric acid and alcohol on carbamylcamphoformeneaminecarboxylic acid is represented in the following equations:



As carbamic acid, in the presence of hydrochloric acid, would cause the formation of ammonium chloride, which was not observed, it is probable that urethane, $\text{NH}_2\text{COOC}_2\text{H}_5$, was the actual product of the reaction, though its presence was not proved, because my interest was confined chiefly to the other substances involved. The shifting of the double bonds ob-

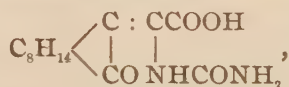
¹ Am. Chem. J., 23, 227.

served in the above formula, representing the formation of a pyrazole derivative, requires no comment, as it is well known that such rearrangement occurs generally in pyrazole formation.¹

The Action of Urea and of the Methylated Ureas on Camphoroxalic Acid.

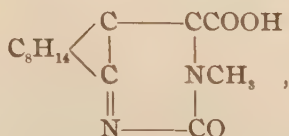
J. Bishop Tingle and W. E. Hoffman, Jr.,² found that when urea and camphoroxalic acid are heated together no compound could be isolated from the tarry reaction product. Under different conditions, I have succeeded in obtaining a urea derivative and also derivatives of methylurea and the symmetrical dimethylurea.

When camphoroxalic acid and urea, in alcoholic solution, are heated under pressure, at 135°, a simple condensation takes place and *formamidylcamphoformeneaminecarboxylic acid*,



is formed. It melts at 192°–194°.

When camphoroxalic acid and methylurea are heated together, without a solvent, or when an alcoholic solution of these substances is heated under pressure, at 100°, condensation takes place with elimination of 2 molecules of water, the product being *1-methyl-2-keto-4,5-camphylmetidiazine-6-carboxylic acid*,



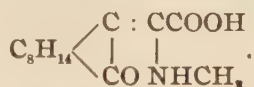
which melts at 154° and is deposited from ethyl acetate solution in slightly yellow, long, prismatic crystals. The fact that a secondary amine group condenses with camphoroxalic acid is significant, and could scarcely be explained on any other basis than that of the unsaturated hydroxy structure of the

¹ Knorr : Ann. Chem. (Liebig), **279**, 188.

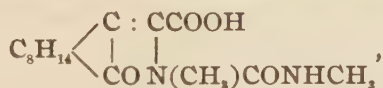
² *Loc. cit.*

latter. It is also noteworthy that the condensation takes place much more readily than with urea itself. This is, perhaps, to be attributed to the more basic character of an alkylated amine as compared with the simpler compound. The influence of methyl in one of the amine groups evidently extends also to the second amine, for it is found to enter into reaction, whereas, in the case of urea, the second amine group is unaffected under similar conditions.

Symmetrical dimethylurea and camphoroxalic acid react readily when a methyl alcoholic solution of the two substances is heated, under pressure, at 100°. There is difficulty in isolating the substance which is formed on account of the tarry nature of the mixture of reaction products; finally, however, a small quantity of a compound was obtained which melted at 104°–105°. A larger amount of a second compound, melting at 77°–78°, was also isolated; it proved to be *methylcamphorformeneaminecarboxylic acid*,



This may have been produced either by the action of methylamine resulting from the decomposition of a part of the dimethylurea during the heating, or, on the other hand, a dimethylurea derivative of camphoroxalic acid, such as



may have been first formed, and then hydrolyzed to the methylamine compound by the treatment employed in the attempts to isolate the product. The fact that the odor of methylamine was not at first perceptible, but developed during this process, and the further fact that a small amount of an unknown compound actually separated, makes the second hypothesis appear the more probable. Hydrolysis of the methylurea compound formulated above would, presumably, yield carbon dioxide, methylamine and methylcamphorformeneaminecarboxylic acid. The latter substance, which, as already mentioned, was

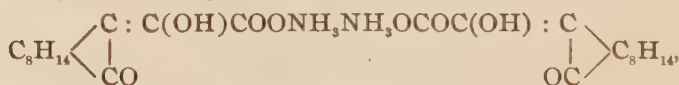
actually obtained, is the missing member of the series of methylamine derivatives of camphoroxalic acid which Bishop Tingle and W. E. Hoffman, Jr.,¹ were unable to prepare under the conditions employed by them.

All attempts to get condensation products of camphoroxalic acid and the unsymmetrical dimethylurea were unsuccessful.

The Action of Hydrazine on Camphoroxalic Acid.

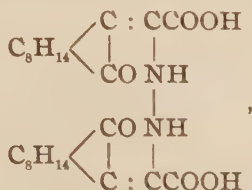
Bishop Tingle and W. E. Hoffman, Jr.,² failed to obtain any reaction when camphoroxalic acid, hydrazine hydrochloride and sodium hydroxide were dissolved in alcohol and heated on the water-bath. The use of barium hydroxide in place of sodium hydroxide gave a similar result. I find that a methyl alcoholic solution of free hydrazine, prepared essentially as described by Lobry de Bruyn,² reacts, at the ordinary temperature, with camphoroxalic acid, yielding three products :

1. *Hydrazine camphoroxalate*,



when in a dry condition, this is a stable salt. It begins to decompose only at 186°, but in solution it dissociates when gently warmed, and the liberated hydrazine condenses with 2 molecules of the acid. Aqueous sodium carbonate also decomposes it, and acidification yields the condensation product, biscamphoformeneaminecarboxylic acid.

2. *Biscamphoformeneaminecarboxylic acid*,



is obtained by the condensation of 1 molecule of hydrazine with 2 molecules of camphoroxalic acid. It is a yellow sub-

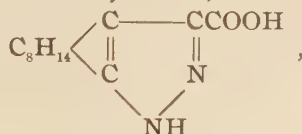
¹ Am. Chem. J., 34, 249.

² Rec. Trav. Chim., 13, 433.

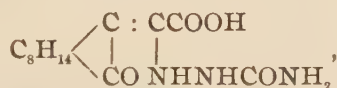
stance which decomposes, without complete fusion, at 150°–155°.

When crystallized from methyl alcohol, it takes up 2 molecules of the alcohol, which are not readily expelled. The crystallized product has a different appearance and different solubilities from the dried substance, and it begins to decompose at 137°. It appears, therefore, that the 2 molecules of solvent are held in closer combination than is usually the case with solvent of crystallization. This is a strong indication of unsaturation in the molecule.

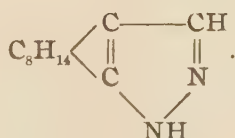
3. *Camphylpyrazolecarboxylic acid*,



is formed by the condensation of 1 molecule of hydrazine with 1 of camphoroxalic acid. It melts at 255°–258°. The same compound was obtained, as previously mentioned, from carbamylcamphoformeneaminecarboxylic acid,

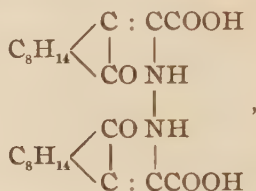


when it is decomposed by heat; its ester was formed by the action of dry hydrochloric acid gas on the same compound, in absolute alcoholic solution. From the facts detailed below, there can be little doubt that this substance is a pyrazole derivative as represented in the above formula. When fused, carbon dioxide is eliminated, and the resulting compound gives a violet color if reduced with alcohol and sodium, and subsequently oxidized with nitric acid and potassium bichromate, indicating that it is *camphylpyrazole*,



This substance remains unmelted up to temperatures as high as 288°.

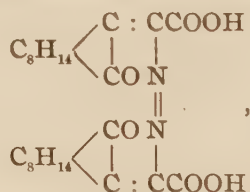
The behavior of biscamphoformeneaminecarboxylic acid,



at high temperatures was then investigated. It was found that at least 3 substances are formed, but a complete study of them has not, as yet, been made. The details of the separation of these compounds from the fused material are given in the experimental part, p. 55; eventually the following products were isolated:

1. A *compound*, $\text{C}_{24}\text{H}_{20}\text{O}_6\text{N}_2$, which differs from the parent material, $\text{C}_{24}\text{H}_{32}\text{O}_6\text{N}_2$, by containing 2 atoms of hydrogen less. This substance crystallizes from ethyl acetate in nodular clusters of fine needles, which have a light yellow color and melt at 222°–223°. The body is an acid, but nothing further was learned regarding its constitution.

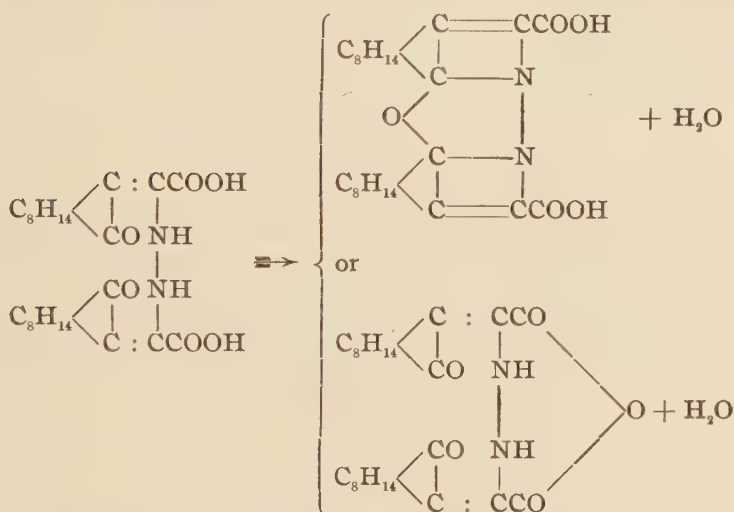
2. A *compound*, which is also an acid and is isomeric with the preceding substance. It melts at 232° and has a dull yellow color, but is usually tinged with red, and its solutions, on standing, become red and deposit red crystals which have practically the same melting point as the yellow substance. The colored material may, perhaps, have an azo structure, such as



but as the pure compound is only slightly colored, this particular formula would hardly apply to it.

3. A *compound*, the analysis of which gave the formula

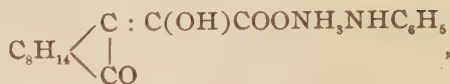
$C_{24}H_{30}O_5N_2$. The substance was, however, obtained in such small quantity that the results require confirmation. If this formula should prove to be correct, the substance is formed from the parent compound, biscamphorformeneaminecarboxylic acid, by elimination of water, thus :



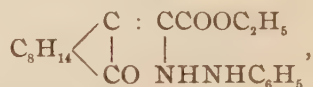
So far as my limited knowledge permits the expression of an opinion, I incline to favor the first of these formulas. The substance crystallizes from ethyl acetate in light yellow, translucent prisms, which melt at 221° . The quantity of material available was too small to permit a more thorough examination of this compound at present, but in the immediate future it is planned to continue the investigation of all three of these substances in this laboratory.

The Action of Phenylhydrazine on Camphoroxalic Acid.

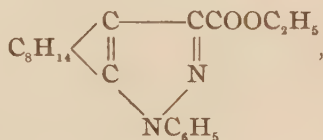
In view of the results which were obtained by the action of hydrazine on camphoroxalic acid, it appeared desirable to extend the investigation to the action of phenylhydrazine on camphoroxalic acid. In the course of some work on the subject, Bishop Tingle had prepared the following derivatives of this base :

1. Phenylhydrazine camphoroxalate (?),¹

melting at 214°–215°, with previous darkening. This had been prepared only once, in very small quantity, and had not been analyzed.

2. Ethyl camphoroxalate phenylhydrazide,²

prepared by condensing ethyl camphoroxalate and phenylhydrazine. It melts at 212°. The corresponding methyl ester was also obtained from methyl camphoroxalate.³

3. Ethyl camphylphenylpyrazolecarboxylate,⁴ m. p. 114°,

and the corresponding methyl ester,⁵ m. p. 80°.5–81°.5, were prepared by the condensation of the respective phenylhydrazides with dehydrating agents.

4. Camphylphenylpyrazolecarboxylic acid,⁶ m. p. 197°, was derived by hydrolysis from both of the preceding esters.

In the course of the present investigation I have obtained camphylphenylpyrazolecarboxylic acid directly from camphoroxalic acid. In addition, it has been found possible to isolate a new compound, the primary reaction product when camphoroxalic acid, or potassium camphoroxalate and phenylhydrazine are brought together at the ordinary temperature. This is the *addition compound*,

¹ Am. Chem. J., **20**, 328 (1898).

² J. Chem. Soc., **57**, 655 (1890). Am. Chem. J., **19**, 402 (1897); **20**, 338 (1898); **21**, 258 (1899).

³ *Ibid.*, **20**, 335.

⁴ *Ibid.*, **19**, 403.

⁵ *Ibid.*, **20**, 336.

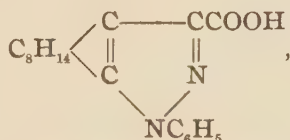
⁶ *Ibid.*, **19**, 405; **20**, 336.



which melts at 120° and crystallizes in very fine, yellow needles. It is quite stable, and can be boiled in weakly dissociating solvents like ether, chloroform and benzene without decomposition. Over sulphuric acid, in a vacuum desiccator, it remained unchanged after standing for 2 months. The possibility of the compound being a salt is excluded by its formation from potassium camphoroxalate.

The stability of this addition compound is another strong argument in favor of the unsaturated hydroxy structure for camphoroxalic acid. A few addition products of phenylhydrazine with true ketones have been isolated; several esters of oxalacetic acid¹ and of dioxysuccinic acid² form such derivatives when the reaction takes place at a low temperature, but otherwise, by the elimination of water, the reaction proceeds to the formation of phenylhydrazones. The addition compounds of the esters of dioxysuccinic acid lose water when left standing either alone, or covered with ether or alcohol. The corresponding compound with ethyl oxalacetate is changed to the hydrazone by warming its solutions; and when it was allowed to remain for 12 days, in a vacuum desiccator, over sulphuric acid, it was quantitatively transformed to the phenylhydrazone. It is evident, therefore, that the addition compound with camphoroxalic acid is not to be classed with the addition products of true ketones and phenylhydrazine.

This compound, after being boiled for some time with alcohol, or when fused, condenses to camphylphenylpyrazolecarboxylic acid,



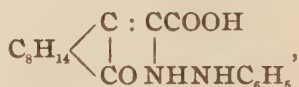
the melting point of which was observed to be 196° instead of

¹ W. Wislicenus and Max Scheidt: Ber. d. chem. Ges., **24**, 3006 (1891).

² Anschütz and Pauly: *Ibid.*, **28**, 66 (1895).

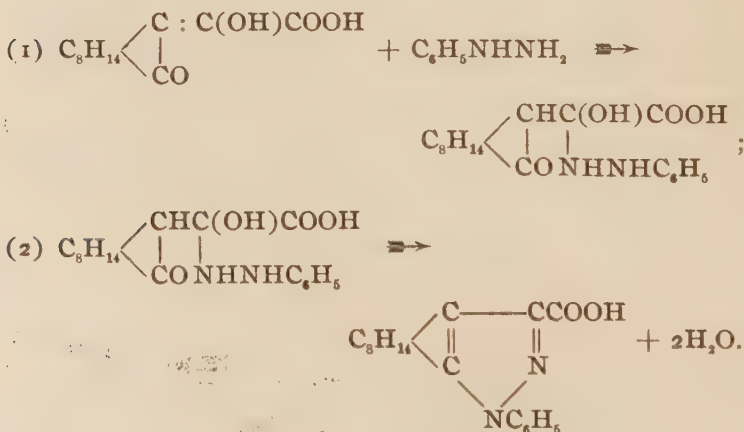
197°, as previously recorded. In the former description of this substance,¹ it was noted that crystals containing 0.5 molecule of benzene were deposited from that solvent. It is now found that the compound crystallizes very readily from alcohol with 1 molecule of alcohol of crystallization.

Attempts to eliminate 1 molecule of water from the addition compound, so as to form the phenylhydrazone of camphoroxalic acid,



were unavailing. The condensation always went further, and 2 molecules of water were eliminated, giving the pyrazole derivative. Unsuccessful attempts were also made to obtain the "phenylhydrazine camphoroxalate" previously described. It appears, therefore, that the formation of this substance, whatever be its nature, depends on some slight variations of experimental conditions which were not noted at the time when the original experiment was carried out, and which I have been unable to reproduce.

The action of phenylhydrazine on camphoroxalic acid may be expressed by the equations :

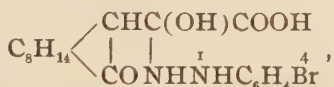


¹ *Loc. cit.*

The Action of Parabromophenylhydrazine on Camphoroxalic Acid.

I extended the investigation so as to include a study of the action of parabromophenylhydrazine on camphoroxalic acid, partly in order to ascertain the effect of the negative bromine atom on the properties and stability of the condensation products, and partly in the hope of preparing some substances belonging to types which were not represented by the compounds which I had succeeded in isolating from hydrazine and from phenylhydrazine. As the result of my experiments, the following 5 derivatives have been obtained :

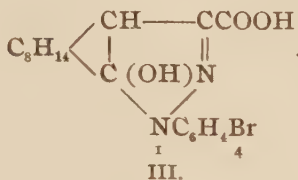
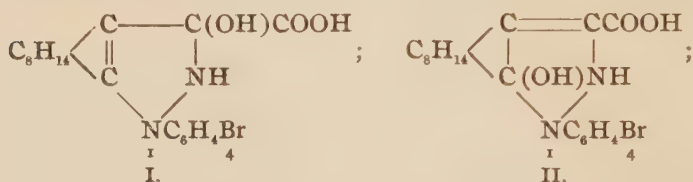
1. *An addition compound,*



corresponding to the addition compound obtained with phenylhydrazine. It is formed, together with the next compound described, whenever parabromophenylhydrazine and camphoroxalic acid are brought together in solution, at the ordinary temperature, and the reaction proceeds in the same way when the solution is heated. The substance melts at 149° and crystallizes in fine, yellow needles—a deeper yellow than that of the corresponding phenylhydrazine derivative. The stability of the compound is such that it is unaffected by heating with acetic anhydride, on the water-bath, for an hour. No products formed by the addition of amines to aldehyde or ketone groups have shown a comparable degree of stability, and although the facts can best be explained by supposing that the addition has taken place at the double linkage in the group $>\text{C}:\text{COH}-$ (*vide* pp. 6, 9), yet it does not account for this stability.

2. The second compound, which is always obtained with the preceding one, melts at 172° . In some experiments, compound number 1 separated first from the solvent, and then the second substance; in other experiments the order of separation was exactly reversed, and sometimes both compounds came down simultaneously. I was unable to ascertain exactly what conditions determine which substance shall precipitate first. This behavior furnishes another illustration of the considera-

ble differences in results which are brought about by relatively minute variation in the experimental conditions, a fact that must be constantly kept in mind in dealing with substances belonging to this class. The compound under discussion differs in composition from the additive compound by 1 molecule of water ; but in the fact that it is not vigorously attacked by concentrated nitric acid, and in its crystallizing power, it resembles the pyrazole derivatives rather than the hydrazides. It appears, therefore, to have the constitution expressed by one of the following formulas :

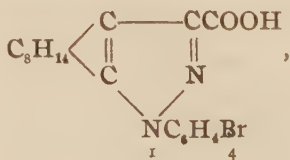


The addition compound being



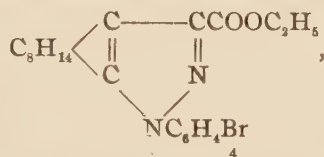
it seems most probable to suppose that the second nitrogen atom combines with the carbonyl of the camphor ring, with the elimination of water, which would then give the structure represented in Formula I. Further work will be necessary to decide this point.

3. *Camphylparabromphenylpyrazolecarboxylic acid,*

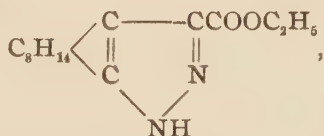


melting at 215° , is formed when either of the two compounds just described is fused. It is interesting to note that the addition compound loses 2 molecules of water at once, instead of first losing 1 molecule and forming the intermediate product, (2) although the latter is a very stable substance. The same conduct is characteristic of the addition compound with phenylhydrazine. This compound (m. p. 215°) is colorless, and crystallizes from benzene in nodular clusters of minute needles.

4. *Ethyl camphylparabromphenylpyrazolecarboxylate*,

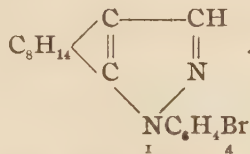


was obtained by treating the addition compound, m. p. 149° , with absolute alcohol, saturated with dry hydrochloric acid, at 0° . It melts at 107° and crystallizes from acetone in magnificent, triclinic crystals. In contrast to ethyl camphylpyrazolecarboxylate,



this substance shows no basic properties.¹

5. A compound, not analyzed, which is probably *camphylparabromphenylpyrazole*,



It is formed by fusing camphylparabromphenylpyrazolecarboxylic acid, carbon dioxide being eliminated. The substance is extremely soluble in all the ordinary organic menstrua, and remains as a gummy mass after the solvent has evaporated

¹ Vide p. 15.

spontaneously. It was not found possible to purify the body sufficiently for analysis.

Of these five compounds, it is seen that the first two have an important bearing on the structure of camphoroxalic acid and tend to confirm the unsaturated hydroxy formula.

The Hydration Product of Camphoroxalic Acid.

In order to obtain, if possible, further evidence of the unsaturated character of camphoroxalic acid, an investigation was undertaken of the hydration product obtained by Bishop Tingle¹ when the acid is heated, under pressure, with aqueous solutions of mineral acids. The substance in question has the composition of camphoroxalic acid plus 2 molecules of water and, in alcoholic solution, gives a blue color with ferric chloride. It was prepared by the use of sulphuric acid as described in the earlier paper², but difficulty was experienced in working with it because of its extremely ready reversion to camphoroxalic acid. It was found that 4 equivalents of sodium carbonate are required to neutralize it, which indicates that there are 3 hydroxyls present, besides the carboxyl. This confirms the analysis previously published³ and indicates that the water is not present as water of crystallization.

With aniline and semicarbazine, respectively, at the ordinary temperature, products were formed which were found to be identical with the corresponding camphoroxalic acid derivatives, but with hydroxylamine, what appears to be a new substance was obtained which melts at 181°-182°, but has not been investigated. The work was not pushed further because of the difficulty of obtaining the pure hydrated acid in quantity.

Summary of the Points Bearing on the Structure of Camphoroxalic Acid.

In the introduction to this paper, several facts were mentioned⁴ as having contributed to the belief that camphoroxalic

¹ Am. Chem. J., 20, 329 (1898).

² Loc. cit.

³ Loc. cit.

⁴ Vide p. 6.

acid is not a true diketone, but an unsaturated hydroxy ketone, *viz.* :

1. The production of a stable addition product with hydroxylamine; and also the formation of addition products with diethylamine and dimethylamine.

2. The formation of a monacetyl derivative with acetic anhydride.

3. The hydrolysis with barium hydroxide, yielding oxalic acid and camphor.

4. The production of a phenylhydrazide instead of a phenylhydrazone.

In this investigation the following additional facts have been discovered which tend to confirm the unsaturated hydroxy structure :

1. Methylurea reacts readily with camphoroxalic acid—much more readily than does urea itself. Both the primary and secondary amine groups enter into the condensation, forming a metadiazine derivative. The condensation of a secondary amine group with a ketone is less easily explained than its reaction with the group $>\text{C}:\text{C}(\text{OH})-$. Symmetrical dimethylurea also appears to react with camphoroxalic acid, and Mr. Williams, in this laboratory, has prepared a condensation product with symmetrical acetylphenylhydrazine, both of which facts argue for the enolic form of the acid.

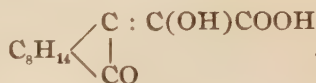
2. Camphoroxalic acid yields an addition product with phenylhydrazine, which is much more stable than any addition products from true ketones which have ever been observed hitherto.

3. Parabromphenylhydrazine yields a still more stable addition product.

4. With parabromphenylhydrazine a ring compound is obtained in which both the keto (or the keto and the enolic) groups have reacted, but with the elimination of only 1 molecule of water. These last three facts are entirely beyond the range of common experience with ketones, and must be explained by the enolic hypothesis.

The general result of this investigation has been, therefore,

to strengthen the view that camphoroxalic acid should be represented by the formula

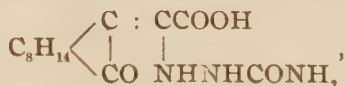


The various derivatives thus far obtained by the action of the amines studied in this investigation are represented in the following table, pp. 31-35, and the relations existing between them are indicated.

EXPERIMENTAL.

In the preparation of camphoroxalic acid, one or two minor changes were made in the method as described by Bishop Tingle and W. E. Hoffman, Jr.¹ Instead of 400 cc. of petroleum ether for each portion of the reacting substances, 350 cc. were used, and satisfactory results were obtained. In distilling the petroleum ether from the reaction product, sufficiently diminished pressure was employed to keep the temperature of the liquid in the flask below 110° to the end of the operation. No difficulty was experienced in accomplishing this with the ordinary water suction-pump. Otherwise the substance was prepared exactly as described by the authors mentioned.

The Supposedly Isomeric Semicarbazine Derivatives of Camphoroxalic Acid.—In the course of some earlier work on camphoroxalic acid derivatives, J. Bishop Tingle and Alfred Tingle² found what appeared to be two isomeric compounds,



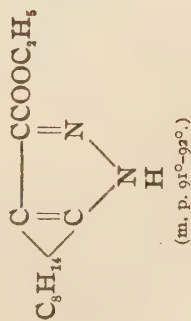
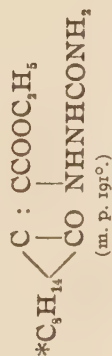
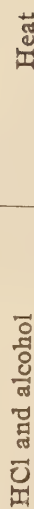
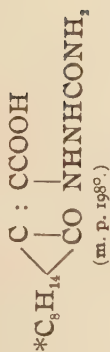
formed when semicarbazine hydrochloride (2 mols.), camphoroxalic acid (1 mol.) and potassium hydroxide (3 mol.) were heated at 100°, for 4 hours, in a closed tube, with alcohol as a solvent. One substance was described as soluble in ether, and melted at 218° when crystallized from acetone; the other was insoluble in all neutral, organic media, and melted at 209°-210° when crystallized from glacial acetic acid. In a later

¹ Am. Chem. J., 34, 235 (1905).

² *Ibid.*, 23, 224 (1900).

Table I.—Derivatives of Camphoroxalic Acid with:

SEMICARBAZINE.



* Previously prepared.

† Identical.

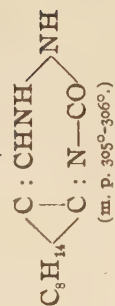
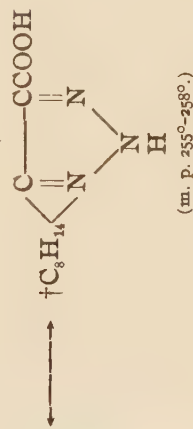
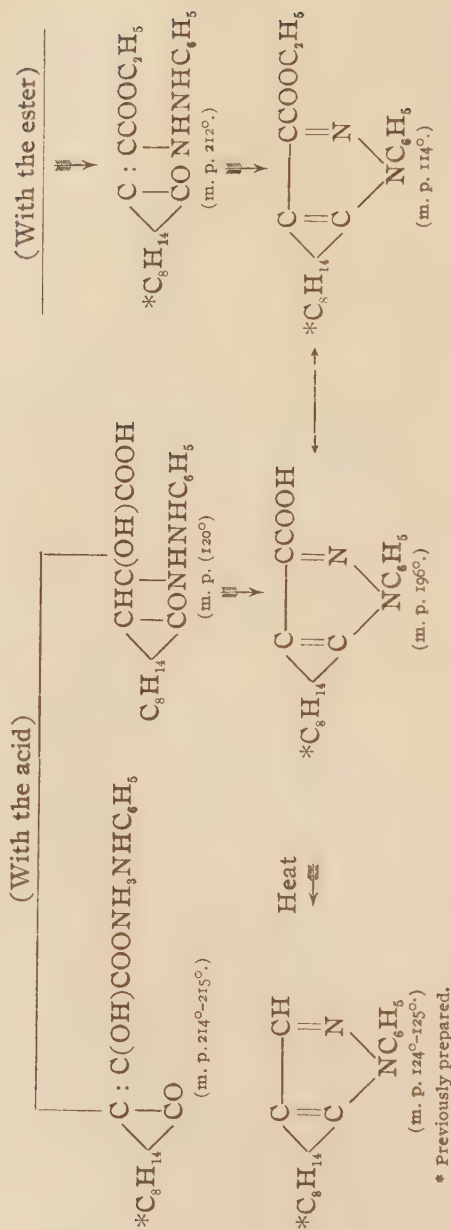


Table I.—Derivatives of Camphoroxalic Acid with (Continued):

UREA.	METHYLUREA.	SYN. DIMETHYLUREA.	UNSYM. DI-METHYLUREA.
$\begin{array}{c} \text{C}_8\text{H}_{14} \diagup \text{C} : \text{CCOOH} \\ \\ \text{CO} \text{ NHCONH}_2 \\ \text{(m. p. } 192^\circ\text{--}194^\circ\text{.)} \end{array}$	$\begin{array}{c} \text{C}_8\text{H}_{14} \diagup \text{C} = \text{CCOOH} \\ \quad \\ \text{C} \quad \text{NCH}_3 \\ \quad \\ \text{N} \quad \text{CO} \\ \text{(m. p. } 154^\circ\text{.)} \end{array}$	$\begin{array}{c} \text{C}_8\text{H}_{14} \diagup \text{C} : \text{CCOOH} \\ \\ \text{CO} \text{ N(CH}_3\text{)CONHCH}_3 \\ \text{(m. p. } 104^\circ\text{--}105^\circ\text{.)} \end{array}$	$\begin{array}{c} \text{C}_8\text{H}_{14} \diagup \text{C} : \text{CCOOH} \\ \\ \text{CO} \text{ NHCH}_3 \\ \text{(m. p. } 77^\circ\text{--}78^\circ\text{.)} \end{array}$
		$\begin{array}{c} \text{C}_8\text{H}_{14} \diagup \text{C} : \text{CCOOH} \\ \\ \text{CO} \text{ N(CH}_3\text{)CONHCH}_3 \\ \text{(m. p. } 104^\circ\text{--}105^\circ\text{.)} \end{array}$	$\begin{array}{c} \text{C}_8\text{H}_{14} \diagup \text{C} : \text{CCOOH} \\ \\ \text{CO} \text{ NHCH}_3 \\ \text{(m. p. } 77^\circ\text{--}78^\circ\text{.)} \end{array}$

Table I.—Derivatives of Camphoroxalic Acid with (Continued):

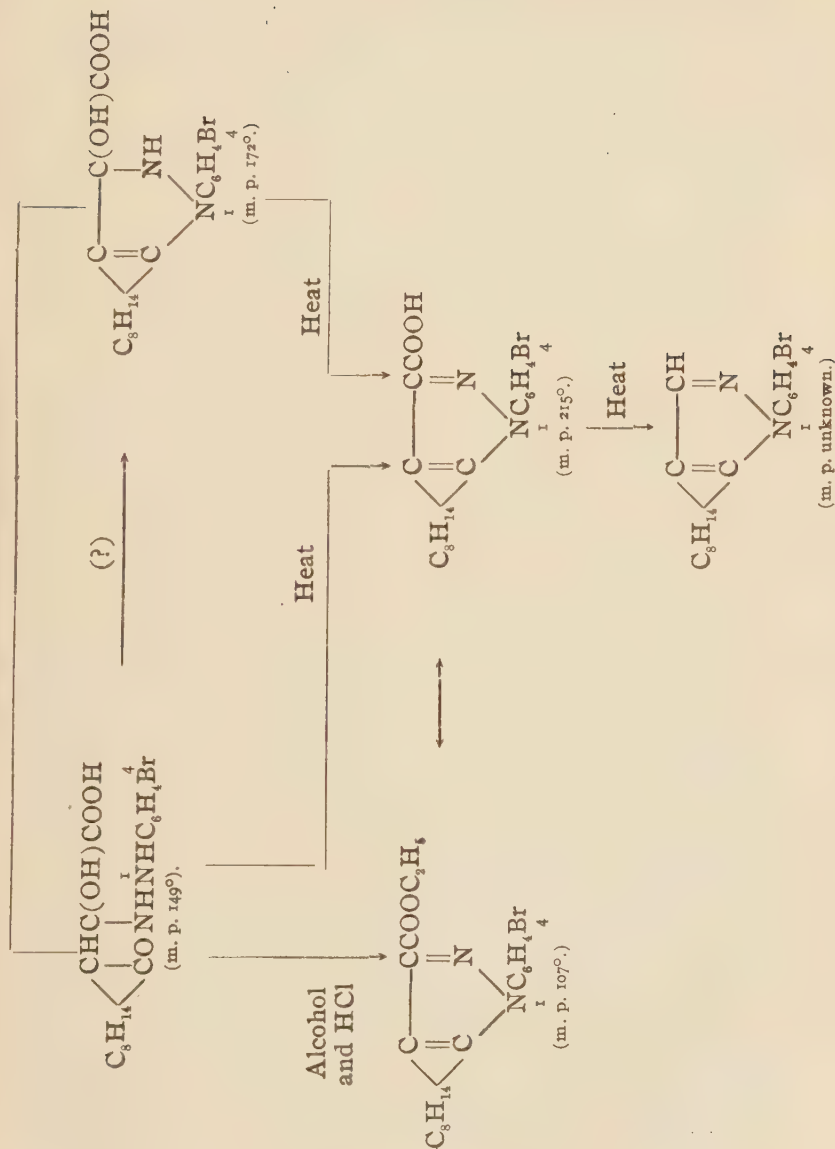
PHENYLHYDRAZINE.



* Previously prepared.

PARABROMOPHENYLHYDRAZINE.

35



paper, J. Bishop Tingle and W. E. Hoffman, Jr.,¹ described two substances obtained by boiling on the water-bath an aqueous-alcoholic solution of semicarbazine hydrochloride (2 mols.), potassium acetate (2 mols.) and camphoroxalic acid (1 mol.). Evaporation of most of the alcohol and the addition of water precipitated a substance which could be crystallized from alcohol and which melted at 200° . It had the same composition as the two compounds referred to above. When this substance was crystallized from glacial acetic acid its melting point was found to be 209° – 210° , and it was, therefore, supposed to be identical with the "insoluble compound" described in the earlier paper. In both these papers the experiments were expressly stated to be only of a preliminary nature.

I have made a further investigation of the action of semicarbazine on camphoroxalic acid, in order to try to throw light on this supposed isomerism. First the experiment in which the substances reacted in a closed tube was carried out, and the product treated exactly as described by Bishop Tingle and A. Tingle. After evaporation of the alcohol and acidification of the residue, the precipitate was washed repeatedly with ether and the filtrate extracted three times with fresh portions of the same solvent. The substance left by evaporation of the combined ethereal residues was crystallized twice from acetone, and the material left undissolved by ether was crystallized twice from glacial acetic acid, by the addition of alcohol. The melting-points of these two portions of the reaction product were then compared by determining both simultaneously, in tubes attached to the same thermometer. They melted at exactly the same temperature.

The reaction was next carried out in the manner described by Tingle and Hoffman. Potassium acetate was used to liberate the semicarbazine from its hydrochloride, and the mixed components were boiled on the water-bath until the alcohol was almost entirely evaporated. The crystalline substance, obtained by dilution with water, was recrystallized from alcohol and a part of the recrystallized product was boiled with glacial acetic acid for a few minutes and crystallized by the addition

¹ Am. Chem. J., **34**, 251 (1905).

of alcohol. The two portions, one from alcohol and one from acetic acid, were found to melt at exactly the same temperature when heated simultaneously. Boiling vigorously in glacial acetic acid for half an hour did not change the substance. The compound, when dissolved in potassium carbonate solution and precipitated by acid, appeared in a gelatinous form, but this, when filtered and dried, still melted at the same temperature as before. It was also found that the two substances obtained by the method first described, and the two obtained by this second process, showed identical melting points when any two of them were compared by heating simultaneously in tubes attached to the same thermometer. Furthermore, a mixture of any two of them, when tested in the same manner with each one of the unmixed substances, showed no change in melting point. Samples of the compounds prepared by Bishop Tingle and A. Tingle and by Bishop Tingle and Hoffman were available; therefore the question was further tested by making an exhaustive comparison of these with each other, and with the newly prepared material. With every possible mixture of equal parts of any two of them, the results, in every case, showed that all the preparations were identical.

In the work described above, it was found that the observed melting point varied widely with the rate of heating, and to make accurate comparisons was possible only by attaching 2 capillaries, containing portions of the two substances to be compared, to the thermometer bulb at the same time, and heating them together. The following data on the variation of the melting-point of this semicarbazine derivative were obtained by experiment. In all cases, the capillary containing the substance was placed in the melting point bulb when the thermometer registered 190° , and the heating was begun at once. Capillaries of about the same size were used in all these determinations.

Table II.

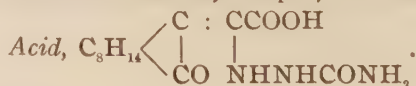
	Rate of rise (above 190°).	Time required.	Observed melting point.
1	2° per minute	5 min. 15 sec.	200°.5
2	4° " "	4 " "	205°.5
3	6° " "	3 " "	208°
4	8° " "	2 " 20 "	209°
5	9° " "	2 " 10 "	209°.5
6	15° " "	1 " 5 "	217°

It was subsequently found that if the substance is heated still more slowly, it melts at 198°; but it will not melt lower than that even with an hour's heating. This must, therefore, be considered the true decomposing temperature of the compound. From the results obtained by Bishop Tingle and A. Tingle,¹ it is evident that an unusual sensitiveness of this compound to slight traces of impurity is a further factor in the variation in melting point.

The substance is rather sparingly soluble in both alcohol and acetone and, when pure, it is practically insoluble in ether. When the crude reaction product is washed with ether, however, the resinous matter which is present appears to render the compound somewhat soluble, which explains why some of it was found in the ethereal washings. The varying data previously recorded in regard to both the solubility and the melting point of this substance are, therefore, satisfactorily explained.

Many other derivatives of camphoroxalic acid, especially those with high melting-points, show a sensitiveness to the rate of heating similar to that described above, though not usually in so marked a degree. The melting points recorded throughout this work are those observed with very slow heating.

The Action of Heat on Carbamylcamphoformeneaminecarboxylic



As stated in the theoretical portion of this paper, at least 3 compounds are formed by heating carbamylcamphoformeneaminecarboxylic acid, *viz.* :

¹ *Loc. cit.*

1. Hydrazodicarbonamide, m. p. 245° .
2. Camphylpyrazolecarboxylic acid, m. p. 255° – 258° .
3. Camphyl-3-keto-1,2,4-heptatriazine, m. p. 305° – 306° .

The experiments were carried out as follows :

The substance was heated in test tubes of 15 mm. diameter, about 3 grams being contained in each. The test tubes were placed in a sulphuric acid-bath in which a thermometer was suspended. It was found that, even when the temperature was raised very slowly, no fusion took place below 198° . After the mass began to fuse the temperature was kept between 196° and 200° , for 20 minutes. Water and carbon dioxide were evolved, neither of them abundantly.

The cooled mass was hard and brittle, with a reddish-brown color and a nitrile-like odor. The odor of camphor was also slightly perceptible. The separation of the products of reaction involved considerable difficulty, but finally the following method was found to be satisfactory :

The powdered mass is treated with cold acetone, filtered and washed repeatedly with acetone. The undissolved portion is then boiled several times with portions of alcohol until the substance still left undissolved is colorless. It is then filtered and washed with alcohol. The white, insoluble substance melts at 245° . The alcohol filtrates are collected and evaporated to crystallization, yielding a yellow substance melting at 305° – 306° . It is purified by boiling with acetone, filtering and washing with acetone. The undissolved material is then recrystallized from alcohol until pure. All the acetone filtrates from the first treatment of the fused material, as well as from the operations just described, are brought together, and the acetone evaporated. A tarry mass remains; by careful treatment with a small amount of cold acetone, much of the tarry matter can be dissolved, leaving a granular substance which is further purified by filtering and washing with a little acetone. Two or three recrystallizations from acetone give a nearly pure, colorless body, crystallizing in small prisms. When pure, it softens at about 250° , shows marked decomposition at 255° and fuses completely at 258° . More of this

compound can be recovered from the tarry mass by treating it with sodium carbonate solution, filtering and acidifying.

Two of these substances were also obtained when camphor-oxalic acid and semicarbazine were allowed to react at 125° , under pressure. Eight and eight-tenths grams of camphoroxalic acid (1 mol.), 8.8 grams of semicarbazine hydrochloride (2 mols.) and 6.8 grams of potassium hydroxide (3 mols.) were placed in a bomb¹ with 100 cc. of 95 per cent alcohol, and heated for 6 hours, at 124° – 126° . The alcohol was then evaporated and water added. A part of the solid remained undissolved. It was dark from the presence of impurities, but boiling with alcohol removed the color and the compound, being insoluble, was left in nearly pure condition. It was found to be identical with the substance melting at 245° , which was obtained by the fusion of the original semicarbazine derivative. The alcohol solution of the dark impurities was decolorized with animal charcoal, and the alcohol boiled off. A small amount of thick, yellow oil was left which gave a brownish-red color with ferric chloride, in alcoholic solution. It was not further investigated. The aqueous filtrate from the insoluble substance, m. p. 245° , gave, on acidification, a white, finely crystalline substance which softened at 250° and melted at 255° – 258° . It was shown by the mixture test to be identical with the compound of the same melting point which was obtained amongst the products of fusion of the semicarbazine compound.

1. *Hydrazodicarbonamide*.—The compound melting at 245° is soluble in 150–200 parts of boiling water and, on cooling, crystallizes in very thin plates. Two recrystallizations suffice for purification. The substance is insoluble in all the ordinary organic media, and dilute acids and alkalies have no effect upon it. It readily reduces an ammoniacal solution of silver nitrate. Analysis:

I. 0.2290 gram substance gave 0.1705 gram CO_2 and 0.1091 gram H_2O .

II. 0.0933 gram substance gave 37.9 cc. N_2 at 18° and 764 mm.

¹ Somewhat similar to that described by S. F. Acree. *Am. Chem. J.*, **35**, 311.

	Calculated for $C_2H_6O_2N_4$.	Found.
C	20.34	20.30
H	5.12	5.33
N	47.45	47.17

The compound is, undoubtedly, hydrazodicarbonamide, which is formed by heating semicarbazine, elimination of hydrazine taking place.

2. *Camphylpyrazolecarboxylic Acid*.—The substance melting at 255° – 258° is slightly soluble in boiling water, but insoluble in cold. It dissolves in a solution of sodium carbonate and is precipitated by acid, but dissolves in excess of acid. Crystals of the substance are readily soluble in cold, dilute acids, showing that it has basic as well as acidic properties. In alcohol it is extremely soluble, but is readily recrystallized from acetone. The crystals are thick, colorless, prismatic forms, usually aggregated into clusters. Analysis:

I. 0.1844 gram substance gave 0.4478 gram CO_2 and 0.0894 gram H_2O .

II. 0.2330 gram substance gave 0.5615 gram CO_2 and 0.1575 gram H_2O .

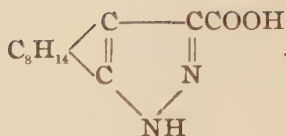
III. 0.1957 gram substance gave 0.4715 gram CO_2 and 0.1387 gram H_2O .

IV. 0.1165 gram substance gave 13.5 cc. N_2 at 25° and 761 mm.

V. 0.1760 gram substance gave 20.1 cc. N_2 at 22° and 755 mm.

	Calculated for $C_{12}H_{16}O_2N_2$.	I.	II.	Found. III.	IV.	V.
C	65.45	66.23	65.73	65.71	. .	. .
H	7.27	6.83	7.56	7.92	. .	. .
N	12.73	. .	. .	. .	12.94	12.83

The same compound was subsequently obtained by the interaction of hydrazine and camphoroxalic acid, and this fact, taken in conjunction with its properties, makes it practically certain that the substance is camphylpyrazolecarboxylic acid,



Its basic properties are attributable to the pyrazole residue.

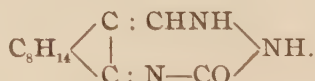
3. *Camphyl-3-keto-1,2,4-heptatriazine*.—The yellow substance, melting at 305° – 306° , which was obtained from the fused material, crystallizes from alcohol in small prisms. The compound does not dissolve in a solution of sodium carbonate. It is fairly soluble in alcohol and difficultly soluble in ether, acetone, benzene and ligroin. From 12 grams of the semicarbazine compound, less than 1 gram of this substance was obtained, and this quantity was reduced to only about 250 milligrams in the process of purification. Hence no extensive study of its properties could be made. Analysis:

I. 0.1630 gram substance gave 0.3917 gram CO_2 and 0.1160 gram H_2O .

II. 0.0902 gram substance gave 15.2 cc. N_2 at 19° and 750 mm.

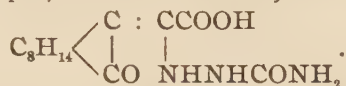
	Calculated for $\text{C}_{12}\text{H}_{17}\text{ON}_8$.	I.	Found.	II.
C	65.75	65.54		. .
H	7.76	7.96		. .
N	19.18	. .		19.11

The compound has the composition of carbamylcamphoformeneaminecarboxylic acid minus the elements of water and carbon dioxide, and hence is assumed to have the structure represented by the formula



The manner of the formation of these three substances from carbamylcamphoformeneaminecarboxylic acid, by the action of heat, is explained in the theoretical part of this dissertation (*vide* p. 12).

*The Action of Hydrochloric Acid and Alcohol on Carbamyl-
camphoformeneaminecarboxylic Acid,*



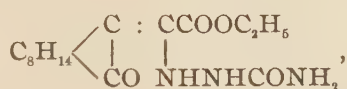
The carbamyl derivative was mixed in a flask with absolute alcohol and dry hydrochloric acid gas was led in to saturation, the temperature being kept low by immersing the flask in ice-water. A flocculent, white substance began to be formed some time before saturation was reached, and eventually appeared in considerable quantity; but when the saturated solution was allowed to stand, even at 0° , it gradually disappeared.

Some of this flocculent substance was filtered out and purified by recrystallization from acetone. The crystals were colorless, but so small as to be in the form of powder. The compound is readily soluble in hot alcohol, but sparingly in cold. It easily dissolves in ether and chloroform, is sparingly soluble in benzene, and insoluble in ligroin. It does not dissolve in sodium carbonate solution. The substance melts at 191° .

Analysis: 0.0843 gram substance gave 0.1798 gram CO_2 and 0.0597 gram H_2O .

	Calculated for $\text{C}_{15}\text{H}_{23}\text{O}_4\text{N}_3$.	Found.
C	58.25	58.17
H	7.44	7.92

The analysis shows the compound to be *ethyl carbamylcamphoformeneaminecarboxylate*,,



which has been previously prepared by Bishop Tingle and A. Tingle, as mentioned in the first part of this dissertation.

The clear, alcoholic solution, saturated with hydrochloric acid, was poured into a large volume of dilute sodium carbonate solution. An emulsion was formed, but on standing over night the emulsified substance collected into a gummy mass which, when filtered and dried, became hard and granular.

It was found to be extremely soluble in methyl and ethyl alcohol, ether, acetone, chloroform, ethyl acetate and benzene. From solution in all of these liquids it appears as a slightly yellow oil, on evaporation of the solvent at the ordinary temperature. This oil gradually solidifies, requiring sometimes several weeks. From methyl alcohol crystals can be obtained if the solution is kept at 0° . The substance is deposited from ligroin, however, in large, beautiful crystals. They belong to the hemimorphic group of the monoclinic system, for they have a single binary axis of symmetry. The orthopinacoid (100) faces are generally the largest faces on the crystal; the

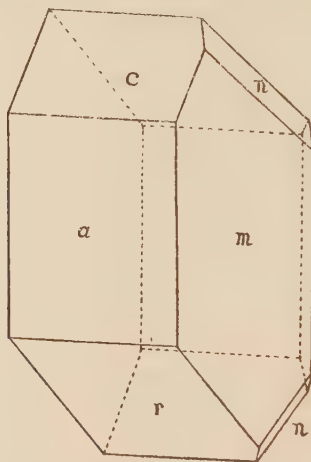


Fig. I.

basal pinacoid (001) and the orthodome (101) are also usually well developed. Two small clinodome faces, opposite each other with respect to the b axis, are sometimes, but not always to be found, and the presence of these betrays the hemimorphic character of the crystals. The following results were obtained on measuring the crystals:

Axes: $a : b : c = 2.0454 : 1 : 2.1002$. $\beta = 54^{\circ} 21'$.

$$a \ m, 100 \wedge 110 = 58^{\circ} 58',$$

$$a \ c, 100 \wedge 001 = 54^{\circ} 21',$$

$$a \ r, 100 \wedge 101 = 61^{\circ} 18',$$

$$r \ c', 101 \wedge 001 = 64^{\circ} 18',$$

$$m \ n, 110 \wedge 011 = 26^{\circ} 48'.$$

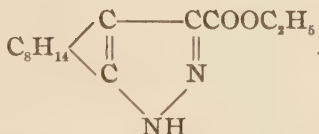
The purified compound melts at 91° – 92° . It is insoluble in sodium carbonate solution. Analysis:

I. 0.1620 gram substance gave 0.4001 gram CO_2 and 0.1170 gram H_2O .

II. 0.1867 gram substance gave 19.3 cc. N_2 at 19° and 736 mm.

	Calculated for $\text{C}_{14}\text{H}_{20}\text{O}_2\text{N}_2$.	Found.
C	67.74	67.36
H	8.06	8.08
N	11.29	11.50

The composition corresponds to that of ethyl camphylpyrazolecarboxylate,



Hydrolysis, effected by warming for a few minutes with potassium hydroxide solution, yielded camphylpyrazolecarboxylic acid (m. p. 255° – 258°), proving the substance to be the one formulated above.

When a portion of the alcoholic hydrochloric acid solution was evaporated to dryness, a solid was obtained which crystallizes readily from acetone in colorless needles, softening at 151° and melting at 156° . An alcoholic solution of this substance yields a precipitate of silver chloride when alcoholic silver nitrate is added. By treatment with a solution of sodium carbonate, ethyl camphylpyrazolecarboxylate is liberated (m. p. 91° – 92°). This substance is, therefore, *ethyl camphylpyrazolecarboxylate hydrochloride*. The stability of this salt is noteworthy and unusual.

The Action of Urea and of the Methylated Ureas on Camphoroxalic Acid.

Urea.—Five grams of camphoroxalic acid and 2.7 grams of urea (2 mols.) were dissolved in 50 cc. of 95 per cent alcohol. When the mixture was heated in a bomb, at 100° , for 5 hours, no reaction took place, but when heated in the same manner at 135° , for 5 hours, a compound was formed which melts at

192°–194°, with evolution of gas. It was separated from the crude product of the reaction by evaporating the alcohol on the water-bath, and washing the residue with chloroform. After being recrystallized twice from methyl alcohol it was in a nearly pure condition, though a slight pink color still clung to it. From its solutions it is deposited in an amorphous form, not in definite crystals.

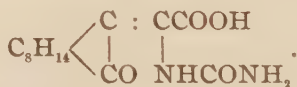
The compound dissolves readily in sodium carbonate solution and is reprecipitated by acidification. Ethyl alcohol dissolves it with ease; acetone, ethyl acetate and chloroform very sparingly; and it is practically insoluble in benzene and ligroin. Analysis:

I. 0.1080 gram substance gave 0.2285 gram CO₂ and 0.0844 gram H₂O.

II. 0.1254 gram substance gave 0.2645 gram CO₂ and 0.0756 gram H₂O.

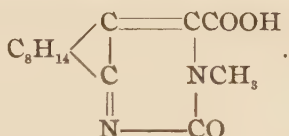
	Calculated for C ₁₂ H ₁₈ O ₄ N ₂ .	I.	Found. II.
C	58.65	57.71	57.53
H	6.77	8.74	6.74

The low results for carbon are due to a slight defect in the absorption apparatus which was not discovered until after the combustions were completed, and time was not available for the preparation of more of the compound. However, the analysis leaves little doubt that the substance is *formamidyl-camphoformeneaminecarboxylic acid*,



Methylurea.—Methylurea and camphoroxalic acid, in equimolecular proportions, were heated together in a test-tube, at 95°, for 30 minutes. The temperature was then allowed to rise to 105° for a few minutes. Water and carbon dioxide were eliminated. The cooled mass was crystallized from ethyl acetate by the addition of ligroin, and was then purified by further recrystallization from ethyl acetate. The product is a slightly yellow substance which is deposited in elongated, prismatic, translucent crystals, melting at 154°. Small crystals

appear quite colorless. The same compound was obtained when equimolecular proportions of methylurea and camphoroxalic acid, in ethyl alcoholic solution, were heated in a bomb for 5 hours, at 100° . The substance dissolves very slowly in cold, aqueous sodium carbonate, but with gentle warming it goes into solution readily and is precipitated unchanged on acidification. In cold alcohol it is sparingly soluble, but dissolves readily on heating: in ether, acetone and chloroform it is very soluble, but not quite so easily in benzene, and only slightly so in ligroin. Analysis shows that the ketonic and enolic groups of camphoroxalic acid have reacted, the product being *1-methyl-2-keto-4,5-camphylmetadiazine-6-carboxylic acid*,



Analysis :

I. 0.1967 gram substance gave 0.4612 gram CO_2 and 0.1224 gram H_2O .

II. 0.2227 gram substance gave 21.2 cc. N_2 at 15° and 742 mm.

	Calculated for $\text{C}_{14}\text{H}_{18}\text{O}_5\text{N}_2$.	I.	Found.	II.
C	64.12	63.95		. .
H	6.87	6.96		. .
N	10.69	. .		10.88

This compound, and also the one from urea, will be investigated more fully at a later date.

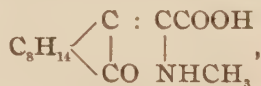
Symmetrical Dimethylurea.—Five grams of camphoroxalic acid (1 mol.) and 4 grams of dimethylurea (2 mols.) were dissolved in 25 cc. of methyl alcohol and heated in a bomb, at 100° – 105° , for 5.5 hours. No definite compound could be isolated from the tarry product of the reaction by the use of the ordinary solvents, on account of the extreme solubility of the material. A portion of the mixture, dissolved in alcohol, was poured slowly into sodium carbonate solution, the precipitated tarry matter was filtered out and the clear solution acidified; a small amount of the substance was precipitated which, when

dried in the air, melted at 104° – 105° . The crude product of the reaction from another experiment, in which the components were taken in the same proportion as before, and the conditions of heating were also identical, was worked up as follows: A part of the methyl alcohol was evaporated and the solution poured into aqueous sodium carbonate. The carbonate solution stood over night, and in the morning had the odor of methylamine. After being filtered, it was acidified, and a precipitate appeared of which a part collected in long needles and the remainder in oily drops, that eventually hardened. The substance is extremely soluble in all the ordinary organic media, but can be crystallized from ligroin, separating in long, colorless, prismatic needles which melt at 77° – 78° . The substance gives a brownish-red color with alcoholic ferric chloride. Analysis:

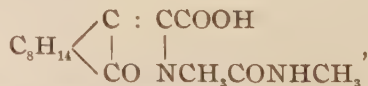
0.1086 gram substance gave 0.2629 gram CO_2 and 0.0787 gram H_2O .

	Calculated for $\text{C}_{13}\text{H}_{19}\text{O}_3\text{N}$.	Found.
C	65.82	66.02
H	8.01	8.10

It is apparently, therefore, a methylamine derivative, *methylcamphoformeneaminecarboxylic acid*,



which has not been previously prepared. Its origin is, perhaps, due to a decomposition of the dimethylurea, resulting in the formation of methylamine, which then reacted with camphoroxalic acid; or, what seems more probable, in view of the fact that the odor of methylamine appeared only after the product had stood a long time in sodium carbonate solution, a dimethylurea derivative,



was first formed, having the melting point 104° – 105° , and this was hydrolyzed by sodium carbonate into methylamine, car-

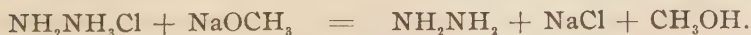
bon dioxide and methylcamphoformeneaminecarboxylic acid. Time was not available for pushing these experiments further, but this matter will also be taken up later, in conjunction with the continuation of the study of the action of urea and methylurea on camphoroxalic acid.

Unsymmetrical Dimethylurea.—Camphoroxalic acid and unsymmetrical dimethylurea, in methyl alcoholic solution, were heated in a bomb, first at 100° – 105° , then, successively, at 125° and at 140° – 145° , in each case for 5 hours. In every experiment the unchanged substances were recovered. After the last heating a very strong odor of dimethylamine was perceptible when the bomb was opened. The experiments were not carried further, as the results gave enough evidence of difference in the action on camphoroxalic acid, of urea and its methyl derivatives to serve my immediate purpose.

The Action of Hydrazine on Camphoroxalic Acid.

A methyl alcoholic solution of hydrazine was prepared by Lobry de Bruyn's method from the hydrochloride, and the strength of the solution approximately determined by means of Fehling's solution. Measured quantities of the solution were then used as desired. For the preparation and titration of the hydrazine solution, I have to thank Mr. W. W. Holland, of this laboratory.

Lobry de Bruyn's directions¹ are not very definite and it may be well, therefore, to state exactly the procedure employed. The quantities given below are convenient and represent suitable proportions of the reacting substances. In a flask fitted with an upright condenser, 100 grams of sodium are added, in small pieces, through the condenser, with the usual precautions, to 150 cc. of absolute methyl alcohol. Forty-two grams (1 mol.) of well pulverized hydrazine hydrochloride are now mixed with the hot mass of sodium methylate (3 mol.). The reaction, which takes place quickly and smoothly, is represented thus :



¹ Rec. Trav. Chim., 13, 433.

After heating a short time, the sodium chloride is filtered out as quickly as possible, with the aid of a suction pump, and the filtrate is distilled from an ordinary fractionating flask. The methyl alcohol which passes off up to about 72° contains only traces of hydrazine. When that temperature is reached the residual, undistilled liquid is placed in a flask to which a Le Bel-Henninge, or similar fractionating apparatus, is attached; it is important to prevent, as far as possible, the hydrazine vapors from coming in contact with the stopper, which should, therefore, be 15–20 cm. above the exit tube. The distillation is then continued under diminished pressure, a manometer being connected with the apparatus. At 30 mm. pressure, the distillate obtained under 50° contained only about 0.5 per cent of hydrazine; between 50° and 60° the fraction contained 2 per cent of the base. The remainder passed over between 60° and 65° , and this solution contained 21 per cent of hydrazine. Throughout the process great care must be taken to avoid unnecessary exposure to the moisture of the air.

Three primary reaction products were obtained by the action of hydrazine on camphoroxalic acid, *viz.*: 1. A compound formed by the action of 1 molecule of hydrazine on 2 of camphoroxalic acid. 2. Hydrazine camphoroxalate. 3. A product resulting from the condensation of 1 molecule of hydrazine with 1 of the acid. The preparation and properties of these substances, in the order mentioned, are described in the succeeding paragraphs.

1. Four grams of camphoroxalic acid were dissolved in the smallest possible amount of methyl alcohol and 3 cc. of a 21 per cent methyl alcoholic solution of hydrazine were added (equimolecular proportions). After standing for 20 hours, the mixture almost completely solidified when it was stirred. The product was recrystallized from methyl alcohol, appearing in the form of long, fine needles which are light yellow in color. It begins to fuse and decompose at about 137° , but complete melting does not take place even at 155° . This crystallized substance was found to contain 2 molecules of methyl alcohol, which are given off slowly at 100° . The compound

obtained by driving off the methyl alcohol is deep yellow in color and decomposes at 150° – 155° , without complete fusion. It dissolves readily in aqueous sodium carbonate solution and is reprecipitated on acidification. With alcoholic ferric chloride it gives a slight, brownish-red color, which soon changes to a yellowish green, due to reduction of the ferric to ferrous chloride. It is so extremely soluble in ethyl alcohol, ether, acetone, ethyl acetate, chloroform and benzene that it cannot be crystallized from them, but is left as a sticky mass by the spontaneous evaporation of any one of these solvents. It is soluble in ligroin with difficulty. The crystals with 2 molecules of methyl alcohol are much less soluble than the alcohol-free material. Analysis:

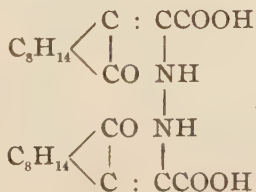
I. 0.3365 gram crystallized substance, when heated at 105° , for 3 hours, lost 0.0395 gram; for 3 hours longer, 0.0020 gram; for 2 hours longer, 0.0004 gram. Total loss, 0.0419 gram.

II. 0.2418 gram crystallized substance gave 11.6 cc. N_2 at 11° and 761 mm.

III. 0.1442 gram substance, dried at 100° , gave 0.3432 gram CO_2 and 0.0987 gram H_2O .

	Calculated for $C_{24}H_{32}O_6N_2 \cdot 2CH_3OH$.	I.	Found.	II.
CH_3OH	12.59	12.45		..
N	5.51	..		5.73
	Calculated for $C_{24}H_{32}O_6N_2$.		Found.	
C	64.86		64.91	
H	7.21		7.65	

The compound, which may be termed *biscamphoformene-aminocarboxylic acid*, is formed by the action of 1 molecule of hydrazine on 2 molecules of camphoroxalic acid and, presumably, has the formula



2. In another experiment, 4 grams of camphoroxalic acid, in methyl alcoholic solution, were treated with 6 cc. of 21 per cent solution of hydrazine (2 mols.) in methyl alcohol. In a short time a bulky, yellow precipitate appeared which was found to decompose between 160° and 172° . After recrystallization from hot methyl alcohol, it decomposed at 150° – 155° , and appeared to be identical with the compound described above. The solubilities of the two substances are markedly different. While the one decomposing at the lower temperature is extremely soluble in all of the ordinary solvents, except ligroin, the new substance is only slightly soluble at the ordinary temperature in methyl and ethyl alcohols, acetone, chloroform, ether, benzene and ligroin. It dissolves on warming, but is changed to the lower melting substance. A solution of sodium carbonate quickly dissolves it, but acidification gives a gelatinous precipitate which is readily soluble in the common organic media, and decomposes at 147° – 155° , the change to the other compound having taken place in this process also. This new substance was purified as much as possible by repeated washings with cold alcohol. The purified material is very light yellow in color and begins to decompose at about 186° , complete fusion taking place only at 245° . With alcoholic ferric chloride it gives a slight, brownish-red color, which soon changes to a yellowish-green, due to the production of ferrous chloride. Analysis:

0.1990 gram substance gave 0.4338 gram CO_2 and 0.1375 gram H_2O .

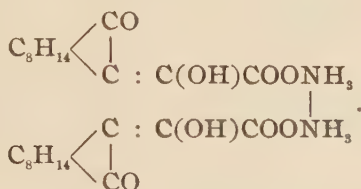
	Calculated for $\text{C}_{24}\text{H}_{36}\text{O}_8\text{N}_2$.	Found.
C	60.00	59.45
H	7.50	7.73

The analysis shows that 1 molecule of hydrazine is combined with 2 of camphoroxalic acid:



On account of its solubility in sodium carbonate solution, it was at first suspected to be formed by the addition of hydrazine to the carbonyl groups, and the change to the other substance

was attributed to the readiness with which water would probably be given off from such an additive compound; it was found, however, that the dried substance, when heated to 160° , for 2 hours, was still unchanged. Further, when a few drops of dilute sulphuric acid were added to a methyl alcoholic solution of the substance, a white, powdery precipitate was formed which was, presumably, hydrazine sulphate. Under similar conditions, the compound decomposing at 150° – 155° was not affected, even after standing 20 hours. It appears, therefore, that the compound is *hydrazine camphoroxalate*,



That it is an unstable salt is shown by the fact that sodium carbonate decomposes it in the cold; and also that, when warmed in the presence of solvents, it dissociates, and the hydrazine liberated reacts with the carbonyl groups.

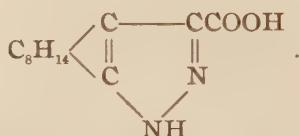
This hydrazine salt was obtained only once. Repeated attempts to prepare it again give only the condensation product.

3. The mother liquors from which the hydrazine salt, or the compound decomposing at 150° – 155° was obtained, gave colorless crystals on standing. When recrystallized from acetone, this substance melted at 255° – 258° . It was also obtained once as the first product when 2 molecules of hydrazine were added to a methyl alcoholic solution of camphoroxalic acid. The compound was observed to be similar in appearance and in melting-point to the acid, $\text{C}_{12}\text{H}_{16}\text{O}_2\text{N}_2$, obtained by the fusion of carbamylcamphoformeneaminocarboxylic acid (Cf. p. 41). Comparison of the two showed them to be identical in all respects and a mixture of them melted at the same temperature as each alone. Analysis:

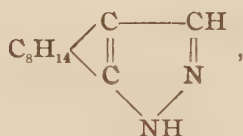
0.1149 gram substance gave 0.2733 gram CO_2 and 0.0793 gram H_2O .

	Calculated for $C_{12}H_{10}O_2N_2$.	Found.
C	65.45	64.87
H	7.27	7.72

As it is formed by the condensation of 1 molecule of camphoroxalic acid with 1 of hydrazine, 2 molecules of water being eliminated, I regard the compound as being camphylpyrazolecarboxylic acid,



In order to obtain, if possible, the simple camphylpyrazole,



some of the acid was subjected to the action of heat. When maintained at 234° for some time, carbon dioxide was evolved copiously and complete fusion eventually took place. The smell of camphor was observed and also a nitrile-like odor. A sublimate of white, prismatic needles, which melted at 217° – 218° , with previous softening, appeared in the upper part of the test-tube containing the material. The cooled mass, which was nearly black, was powdered and washed with hot benzene, which removed most of the color. The residue was recrystallized from alcohol and this treatment repeated, but it failed to remove all of the color and analyses of the product did not give concordant results. The substance separates from alcohol in the form of a fine powder, which darkened at about 275° , but was not fused at 288° . It does not dissolve in sodium carbonate solution. When an alcoholic solution of it is reduced with sodium, and nitric acid and potassium bichromate are added, a beautiful, violet color is produced. This indicates a pyrazole. If the compound is camphylpyrazole, its

high melting point is surprising, as phenylcamphylpyrazole melts at 124° – 125° .¹

Biscamphoformeneaminecarboxylic acid, decomposing at 150° – 155° , was heated at that temperature for 15 or 20 minutes. There was evolution of carbon dioxide and water vapor, and the smell of camphor was perceptible, together with the nitrile-like odor usually observed in heating these compounds. Complete fusion did not take place, but the whole mass appeared to be affected by the decomposition. The cooled product was powdered and treated with hot benzene. A gelatinous mass remained undissolved, which, after being filtered out and dried, became granular and melted at 222° – 223° . The benzene filtrate, when spontaneously evaporated, deposited a gelatinous mass, which was washed with ethyl acetate. The granular solid remaining melted at 232° . The ethyl acetate washings left, on spontaneous evaporation, a red-brown gum in which crystals slowly formed. By washing with small amounts of ethyl acetate these crystals were isolated and then recrystallized from the same solvent. They melted at 221° . When mixed with the above-mentioned substance, melting at 222° – 223° , the mixture melted, not sharply, at 215° , some of the latter compound, which was heated simultaneously in a second capillary tube, melting, as usual, at 222° – 223° . The two compounds have the same color—a light yellow—but the higher-melting one crystallizes from ethyl acetate in fine needles, which aggregate in nodular clusters, while the low-melting one crystallizes from the same solvent in small, translucent prisms.

The compound melting at 222° – 223° is as readily soluble in aqueous sodium carbonate as the substance decomposing at 150° – 155° , and is reprecipitated by the addition of acid. It is very soluble in ethyl and methyl alcohols and acetone, but does not readily dissolve in benzene. After two recrystallizations from ethyl acetate, it was analyzed.

I. 0.1308 gram substance gave 0.3127 gram CO_2 and 0.0895 gram H_2O .

II. 0.0905 gram substance gave 0.2172 gram CO_2 and 0.0623 gram H_2O .

¹ Ann. Chem. (Liebig), **281**, 353.

III. 0.1319 gram substance gave 7.6 cc. N_2 at 20° and 740 mm.

	Calculated for		I.	Found.	III.
	$C_{24}H_{32}O_6N_2$.	$C_{24}H_{30}O_6N_2$.		II.	
C	64.86	65.15	65.20	65.45	. .
H	7.21	6.79	7.65	7.70	. .
N	6.30	6.33	. .	. .	6.41

The analyses are scarcely definite enough to enable one to decide with certainty which of the two formulæ belongs to the compound, but the results indicate that it has the composition of the latter. If such be the case, this substance is formed from biscamphoformeneaminecarboxylic acid, $C_{24}H_{32}O_6N_2$, by the loss of 2 atoms of hydrogen.

The substance melting at 232° has a dull yellow color, slightly tinged with red. It readily crystallizes from ethyl acetate. A brick-red deposit usually occurs on the sides of the beaker in which the solution stands; the mother liquors are always red and deposit the same brick-red substance. This colored material appears to be the original substance, mixed with a slight amount of impurity. It melts, not very sharply, at 230° , and mixing with the pure substance raises the melting point close to 232° , the melting point of the pure compound. Recrystallization from ethyl acetate, however, does not remove the color. The compound dissolves very readily in a solution of sodium carbonate, disappearing instantly. Acidification precipitates it unchanged, m. p. 225° – 227° . Alcohol, ether and acetone dissolve it with extreme readiness, and in benzene it is moderately soluble, but is very sparingly so in ligroin. The specimen analyzed had been recrystallized twice from ethyl acetate. Analysis:

0.1354 gram substance gave 0.3236 gram CO_2 and 0.0914 gram H_2O .

	Calculated for	Found.
	$C_{24}H_{30}O_6N_2$.	
C	65.15	65.18
H	6.79	7.55

The compound appears, therefore, to be isomeric with that melting at 222° – 223° . Further work must be done before

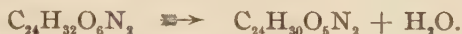
anything can be said with assurance concerning the structure of the two, and even their composition should be tested by additional analyses.

The substance melting at 221° was recrystallized from ethyl acetate and analyzed.

0.0992 gram substance gave 0.2458 gram CO_2 and 0.0662 gram H_2O .

	Calculated for $\text{C}_{24}\text{H}_{30}\text{O}_6\text{N}_2$.	Found.
C	67.66	67.58
H	7.04	7.46

The analysis indicates that the compound is an anhydride of biscamphorformeneaminecarboxylic acid.



Various formulas for such a substance are discussed on page 21. It was impossible to make an extended study of this compound on account of the small quantity of material available; indeed the analysis itself should not be accepted without confirmation, on account of the difficulty of determining the degree of purity attained with so small a quantity of the substance. The investigation of these bodies will be continued in this laboratory.

The Action of Phenylhydrazine on Camphoroxalic Acid.

As mentioned on page 22, the following derivatives of phenylhydrazine and camphoroxalic acid had been prepared before this investigation was commenced: 1. Phenylhydrazine camphoroxalate (?). 2. Ethyl camphoroxalate phenylhydrazide, and the corresponding methyl ester. 3. Ethyl and methyl camphylphenylpyrazolecarboxylate. 4. Camphylphenylpyrazolecarboxylic acid, by the hydrolysis of the esters. I have now obtained an addition compound and have prepared the last-named of the above substances (number 4) directly from camphoroxalic acid, but I have failed in my efforts to prepare phenylhydrazine camphoroxalate.

The Addition Compound.—To camphoroxalic acid (1 mol.) in chloroform solution, phenylhydrazine (2 mols.) was added. In a few minutes the mixture suddenly solidified, the substance

formed having a light yellow color and melting at 120° , with decomposition. It was recrystallized from boiling chloroform. The crystals are long and very fine needles, which are somewhat difficult to manipulate on account of their lightness. The compound is easily dissolved by aqueous sodium carbonate, and acidification reprecipitates it. It is readily soluble in alcohol, ether, chloroform and benzene; sparingly soluble in ligroin, and may be recrystallized from hot benzene as well as from chloroform. From these two solvents it sometimes separates as a transparent, gelatinous mass instead of in crystals. With alcoholic ferric chloride a slight brown color is formed. The addition of concentrated nitric acid causes a violent reaction and the production of an intense, reddish-violet color.

The same substance is obtained when phenylhydrazine reacts, at the ordinary temperature, with camphoroxalic acid in alcohol, ether, or benzene solution. It is also formed when the acid (1 mol.), in alcoholic solution, is neutralized with potassium carbonate and treated with phenylhydrazine (1 mol.). Dilution with water and acidification with acetic acid precipitated the yellow compound, melting at 120° . Five grams of camphoroxalic acid and 2.4 grams phenylhydrazine gave 7.4 grams of the substance. Analysis:

I. 0.2367 gram substance gave 0.5602 gram CO_2 and 0.1495 gram H_2O .

II. 0.2559 gram substance gave 0.6043 gram CO_2 and 0.1644 gram H_2O .

III. 0.1910 gram substance gave 14.7 cc. N_2 at 19° and 747 mm.

IV. 0.1970 gram substance gave 15.6 cc. N_2 at 20° and 746 mm.

	Calculated for $\text{C}_{18}\text{H}_{24}\text{O}_4\text{N}_2$.	I.	II. Found.	III.	IV.
C	65.12	64.55	64.41	. .	. .
H	7.28	7.07	7.19	. .	. .
N	8.49	. .	. .	8.69	8.88

The analysis shows that the substance is an addition compound of camphoroxalic acid and phenylhydrazine, and its formation from potassium camphoroxalate excludes the possi-

bility of its being a phenylhydrazine salt of the acid. It must, therefore, be represented by the formula



In the hope of eliminating a molecule of water, some of this compound was placed in a vacuum desiccator containing sulphuric acid, and allowed to stand for 2 months. No change took place. This, and the further fact that its solutions can be boiled, distinguish the substance from the very unstable additive compounds of phenylhydrazine with ketones which have been isolated. This point has been discussed more fully in the theoretical part (*vide* p. 23).

The chloroform mother-liquor, containing the excess of phenylhydrazine from the reaction described above, if allowed to stand a few days at ordinary temperatures, deposited the characteristic, glistening, flaky crystals of phenylhydrazine hydrochloride. The substance was identified by the fact that it gives a precipitate of silver chloride when treated, in alcoholic solution, with silver nitrate; and when aqueous alkali comes in contact with it, phenylhydrazine is liberated.

The purified hydrochloride was found to melt at 233° , with previous darkening, if heated at a slow rate, instead of 240° as given by Broche,¹ or 240° – 243° as given by Autenreith.² The decomposition of chloroform by phenylhydrazine, with the formation of phenylhydrazine hydrochloride, has been previously noted and investigated by Brunner and his co-workers.³

After removal of the phenylhydrazine hydrochloride from the chloroform mother-liquor, it deposited, on standing at the ordinary temperature, a small amount of a substance melting at 196° . When the compound melting at 120° was boiled for 15 or 20 minutes, in alcoholic solution, or when it was heated to fusion without a solvent, the same substance was obtained in relatively large quantity. The latter reaction takes place at 90° – 100° if this temperature is maintained for several hours;

¹ J. prakt. Chem., [2], **50**, 114.

² Ber. d. chem. Ges., **29**, 1656.

³ *Ibid.*, **30**, 2587 (1897); **31**, 1406 (1898).

complete fusion occurs, with elimination of water. The substance in question was also formed when camphoroxalic acid was heated with 1, 2 or 3 molecules of phenylhydrazine at 95° – 100° , water and a small amount of carbon dioxide being given off in each case. In all these experiments the product was purified by crystallization from alcohol, it being sparingly soluble in cold alcohol and readily in hot. It dissolves very quickly in chloroform, less easily in ether, is readily soluble in benzene and almost insoluble in ligroin. It can be crystallized from benzene as well as from alcohol. Cold, aqueous potassium carbonate dissolves the substance slowly, but on warming a solution is formed quickly, with effervescence. Acidification reprecipitates the substance unchanged.

The crystals deposited from alcoholic solutions were found to have 1 molecule of alcohol of crystallization. Beautiful, colorless crystals were readily obtained which were frequently 5 mm. long and sometimes had a length of 1 cm. They are monoclinic in form, with normal symmetry, *i. e.*, 1 plane and 1 axis of symmetry. The faces observed to be most strongly developed were the basal pinacoid (001), the orthopinacoid

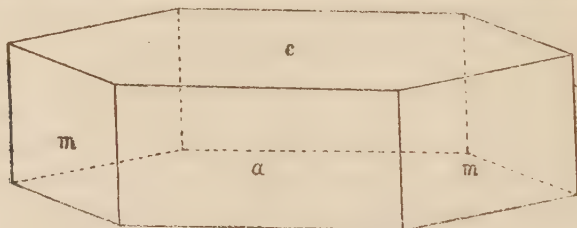


Fig. II.

(100) and the unit prism (110). Orthodome and unit pyramid faces were frequently noticed, but were not well developed. The crystals are flattened parallel to the *b* axis, and present a tubular appearance, as shown in Fig. II. They soon lose their luster, even when kept in closed vessels. The following results were obtained on measuring the crystals :

Axes : $a : b : c = 0.9442 : 1 : x$. $\beta = 68^{\circ} 15'$.

$$a \ m, 100 \wedge 110 = 41^{\circ} 15',$$

$$a \ c, 100 \wedge 001 = 68^{\circ} 15',$$

$$m \ c, 110 \wedge 001 = 75^{\circ} 15'.$$

No pyramidal forms or domes were found, hence the axis c could not be determined. All of the values given are only approximate, because the crystals which were measured had lost most of their luster. The melting point of the air-dried crystals is not different from that of the substance after expulsion of the alcohol of crystallization. Analysis of the substance dried in a desiccator :

I. 0.2342 gram substance gave 0.5985 gram CO_2 and 0.1606 gram H_2O .

II. 0.2094 gram substance gave 14.2 cc. N_2 at 19° and 765 mm.

III. 0.2190 gram substance gave 14.85 cc. N_2 at 18° and 766 mm.

IV. 0.1468 gram substance, heated in an air-bath for 3 hours, at 125° – 135° , lost 0.0179 gram.

	Calculated for $\text{C}_{18}\text{H}_{20}\text{O}_2\text{N}_2 \cdot \text{C}_2\text{H}_5\text{OH}$.	I.	Found. II.	III.	IV.
C	70.12	69.70	. .	. .	. .
H	7.65	7.67	. .	. .	. .
N	8.20	. .	7.85	7.90	. .
$\text{C}_2\text{H}_5\text{OH}$	13.45	. .	. .	. .	12.17

Analysis of the substance dried at 125° :

I. 0.2075 gram substance gave 0.5534 gram CO_2 and 0.1302 gram H_2O .

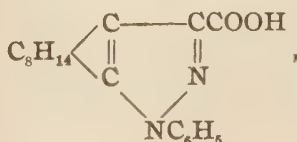
II. 0.1721 gram substance gave 0.4596 gram CO_2 and 0.1085 gram H_2O .

III. 0.2646 gram substance gave 21.8 cc. N_2 at 21° and 755 mm.

IV. 0.2687 gram substance gave 22.7 cc. N_2 at 24° and 748 mm.

	Calculated for $\text{C}_{18}\text{H}_{20}\text{O}_2\text{N}_2$.	I.	Found. II.	III.	IV.
C	72.92	72.72	72.86	. .	. .
H	6.80	7.02	7.05	. .	. .
N	9.47	. .	. .	9.32	9.32

The compound is evidently camphylphenylpyrazolecarboxylic acid,



which was previously made by J. Bishop Tingle¹ by hydrolyzing the ethyl ester, the latter being formed from the phenylhydrazide of ethylcamphoroxalate by the action of heat, by the dehydrating action of hot glacial acetic acid, or of hydrochloric acid, in alcoholic solution. He found that the substance crystallizes from benzene with 0.5 molecule of benzene of crystallization. He also mentions that the acid gives no color with concentrated nitric acid, while the ester gives a pale yellow color. I find that if the solution of the acid, in concentrated nitric acid, is very gently warmed, this pale yellow color appears. An alcoholic solution of ferric chloride gives, with the acid, a red color bordering on orange.

An attempt to make camphylphenylpyrazole carboxylic acid by condensing phenylhydrazine and camphoroxalic acid, in benzene solution, in the presence of fused calcium chloride, did not proceed satisfactorily. The addition compound, melting at 120°, was first formed. The products of the reaction were boiled on a water-bath, in a flask with a return condenser, until this addition compound disappeared, which required several hours. Considerable quantities of phenylhydrazine hydrochloride separated out, the hydrochloric acid doubtless being liberated by the formation of calcium salts of camphoroxalic acid and the acids derived from it by the action of phenylhydrazine. The benzene filtrate from the hydrochloride and the calcium chloride was evaporated to dryness, the residual mass dissolved in alcohol, and the solution poured into a solution of potassium carbonate. Dilution with water and acidification precipitated a small amount of camphylphenylpyrazolecarboxylic acid. No other products of the reaction were found.

J. Bishop Tingle² has described a compound, melting at 214°–215° with previous darkening, which he obtained when camphoroxalic acid and 2 molecules of phenylhydrazine, in anhydrous ethereal solution, were boiled for 2 hours in an apparatus with a return condenser. This compound was supposed to be phenylhydrazine camphoroxalate, but was not analyzed. Attempts were made to obtain the substance again for further

¹ Am. Chem. J., 19, 405.

² *Ibid.*, 20, 328 (1898).

study, but when the ethereal solutions of camphoroxalic acid and phenylhydrazine were poured together, the addition compound, m. p. 120° , was at once formed, the whole mass solidifying and the ether boiling with the heat of the reaction.

Boiling on the water-bath, with a return condenser, for 3 hours, produced no change in the mass, even when more ether was added. The experiment was repeated, both with ordinary ether and with ether dried over sodium, with the same result. Attempts to get the phenylhydrazine salt of camphylphenylpyrazolecarboxylic acid, by treating the acid with excess of phenylhydrazine, were likewise unavailing.

The Action of Parabromphenylhydrazine on Camphoroxalic Acid.

The compounds obtained by the action of parabromphenylhydrazine on camphoroxalic acid correspond fully to those obtained with phenylhydrazine, with the exception of one substance, which has the composition of the addition compound minus 1 molecule of water. Such a body was not obtained in the phenylhydrazine series.

Two compounds, which melt at 149° and 172° , respectively, are formed whenever camphoroxalic acid and parabromphenylhydrazine are brought together in alcoholic solution. What experimental factors determine which shall be produced in larger quantity were not learned. Under seemingly similar conditions, sometimes one and sometimes the other separates first, and in one experiment the two separated at the same time, each in its characteristic crystalline form. When crystals of one substance have been separated and completely removed from the solution, the mother-liquor usually next deposits crystals of the other compound. The length of heating is not the determining factor, for either may be obtained without any heating at all. Although the substance melting at 172° was first obtained by evaporating the solution to a small volume and allowing it to stand, the other compound separated first in another experiment in which the substances, in absolute alcoholic solution, were boiled in a flask with a return condenser for an hour and a half, the solution being evaporated to a small volume and allowed to stand. It is possible that the

concentration of the parabromphenylhydrazine may determine the relative amounts of the two compounds, because it was observed that with a small volume of solvent, and a large excess of this substance, more of the low-melting, additive compound was obtained. The method of procedure given in the succeeding detailed description of the experiments is the one employed when these two substances were obtained for the first time. Repetition of the experiments may or may not give the same results.

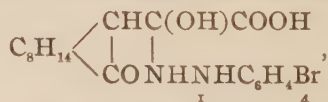
Two and one-half grams of camphoroxalic acid (1 mol.) and 4 grams parabromphenylhydrazine were dissolved in a small amount of alcohol and the solution warmed for a few minutes. The reaction mixture then solidified rather suddenly into a yellow mass. The substance was filtered and recrystallized from alcohol. It forms very slender, yellow needles, which melt at 149° with evolution of gas. The compound is readily soluble in methyl and ethyl alcohols, extremely soluble in acetone and chloroform, fairly so in ether and benzene, but is soluble with difficulty in ligroin. From alcohol or benzene solution it sometimes separates out as a transparent, gelatinous mass. It dissolves readily in aqueous sodium carbonate and is reprecipitated by acidification. With ferric chloride, in alcoholic solution, only a slight brownish color is produced. Concentrated nitric acid attacks it violently, with the formation of a deep red color. Analysis:

I. 0.2409 gram substance gave 0.4603 gram CO_2 and 0.1150 gram H_2O .

II. 0.1801 gram substance gave 0.0786 gram AgBr.

	Calculated for $\text{C}_{18}\text{H}_{23}\text{O}_4\text{N}_2\text{Br}$.	I.	Found.	II.
C	52.53	52.14		. .
H	5.63	5.34		. .
Br	19.46	. .		18.57

The analysis shows it to be an *addition compound*,



corresponding to that formed with phenylhydrazine, m. p.

120°, which it resembles in appearance and behavior. In order to test its stability, it was boiled for 2 hours with absolute alcohol, but it remained unchanged. The same point was further proved by the fact that the compound, when warmed with acetic anhydride to about 75°, for an hour, was precipitated unchanged on dilution with water. Such behavior, as pointed out in the earlier portion of this dissertation, is a strong argument against the substance being a ketone additive compound, of the usual type ascribed to such substances.

Carbon and hydrogen in this compound, and in the others containing bromine which are described subsequently, were determined in the presence of copper oxide, by the method recently worked out by me.¹

Seven and one-half grams of camphoroxalic acid and 6.5 grams (1 mol.) of parabromophenylhydrazine were dissolved in alcohol and boiled on the water-bath to a small volume. On standing over night, crystals were deposited which melt at 172°, with evolution of gas. The substance may be recrystallized readily from alcohol. Very perfect, though not large, crystals are formed which belong to the orthorhombic system. The macrodome (101) and brachydome (011) forms are strongly developed, and the crystals frequently approach the octohedron in shape, but are usually elongated somewhat in the *c* axis. The macropinacoid form (100) is often present as a small face. The crystals are not colorless even after repeated crystallizations, but have a slight brownish tinge. In recrystallizing the substance, crystals of a different kind were sometimes deposited in very small amount. These were light-yellow colored needles, aggregated in fan-like clusters, and were not lustrous like the other variety. They melted at the same temperature, 172°, as the orthorhombic crystals, but were obtained in too small amount for further comparison. The substance is very soluble in ether, acetone and chloroform; readily in methyl and ethyl alcohols; sparingly in benzene; and soluble with difficulty in ligroin. It does not dissolve in aqueous sodium carbonate, even on boiling, and warm alkali hydroxide solution does not dissolve it, but slowly effects hy-

¹ *Am. Chem. J.*, **36**, 531 (1906); Part II. (p. 72) of this dissertation.

drolysis. It is soluble in alcoholic alkali hydroxide, but rapid decomposition takes place, with the formation of a red color, probably due to free parabromophenylhydrazine. However, if an alcoholic solution of the compound is poured into a solution of sodium carbonate it is not precipitated by the addition of water, but comes down unchanged, m. p. 169° , on acidification. Its extreme insolubility in water presumably prevents its going into solution in aqueous alkali.

An alcoholic solution of ferric chloride gives, with this substance, a peculiar, dull brownish-red color, and the addition of water causes a blue fluorescence. Analysis:

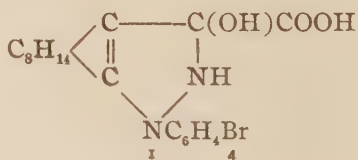
I. 0.2135 gram substance gave 0.4308 gram CO_2 and 0.0982 gram H_2O .

II. 0.2624 gram substance gave 16.2 cc. N_2 at 19° and 758 mm.

	Calculated for $\text{C}_{18}\text{H}_{21}\text{O}_3\text{N}_2\text{Br}$.	I.	Found.	II.
C	54.94	55.03		. .
H	5.38	5.15		. .
N	7.14	. .		7.08

The crystallized substance did not change in weight when heated at 110° , for 2 hours.

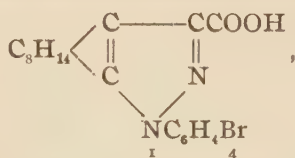
This compound has the same composition as the addition product, melting at 149° , minus 1 molecule of water. The latter is attacked by concentrated nitric acid with almost explosive violence, while the present substance, when treated with the same reagent, goes into solution slowly and quietly, and a pale yellow color is developed. In this respect, as well as in its crystallizing power, it is analogous to camphylphenylpyrazolecarboxylic acid. Hence it seems probable that the compound melting at 172° contains the pyrazole ring, although only 1 molecule of water has been eliminated. As stated in the theoretical part,



seems the preferable one of the three formulæ possible for such a substance.

An attempt was made to acetylate the compound melting at 172° by the action of acetic anhydride. When heated with the anhydride alone, the substance did not dissolve, but on the addition of a few drops of concentrated sulphuric acid, solution took place at once; however, only a tarry mass was formed from which no definite product could be isolated.

Camphylparabromphenylpyrazolecarboxylic acid,



was obtained by the action of heat on either of the two compounds described above. A quantity of the addition compound, which had not been completely purified, was placed in a test-tube and heated in a sulphuric-acid bath, the temperature being raised slowly. At 110° it began to give off water, and partial fusion took place, but eventually the entire mass became solid again and further heating to 135° gave no action except the elimination of a small quantity of carbon dioxide. The cooled mass was brown and brittle. It was powdered and dissolved in boiling benzene. On cooling, a colorless substance was deposited which melts at 215° when heated slowly. The procedure with the compound melting at 172° was similar. It began to decompose after heating for some time at 155° , and partial fusion took place, with the elimination of water. After a few minutes the material again became solid. The cooled mass was treated in the same way as in the case of the addition compound, and the two products were found to be identical.

This new compound dissolves slowly in cold sodium carbonate solution, but readily when warmed. Acidification reprecipitates it. It crystallizes from benzene or alcohol in clusters of small needles, the clusters often being nodular in appearance. It is readily soluble in ether, acetone, chloroform and ethyl acetate, but is almost insoluble in ligroin. Analysis:

0.1937 gram substance gave 0.4095 gram CO_2 and 0.0923 gram H_2O .

	Calculated for $\text{C}_{19}\text{H}_{19}\text{O}_2\text{N}_2\text{Br}$.	Found.
C	57.58	57.66
H	5.10	5.33

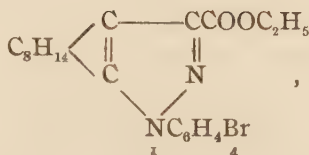
The analysis shows it to be *camphylparabromphenylpyrazole-carboxylic acid*, with the formula given above.

Ethyl camphylparabromphenylpyrazolecarboxylate was obtained by the action of absolute alcohol and hydrochloric acid on the addition compound, m. p. 149° . The latter substance was dissolved in absolute alcohol, and the solution saturated with dry hydrochloric acid gas, the liquid being cooled with ice-water. After standing 2 days, the mixture was poured into water. A slightly yellow substance was precipitated which was filtered, dried and found to melt at 105° . No further precipitate was produced by neutralizing the filtrate with sodium carbonate. To remove any acid that might be present in the precipitated substance it was dissolved in alcohol, the solution was treated with dry sodium carbonate and allowed to stand for several hours. The liquid was then filtered, and the filtrate poured into water. An emulsion was formed which, after the addition of sodium chloride, was extracted with ether. Evaporation of the ether left an oily substance which was readily crystallized from acetone, and purified by recrystallization from the same solvent. Magnificent crystals were formed, which always appeared somewhat yellow, though translucent, but were colorless when powdered. Some of the crystals were nearly 1 cm. in length. They belong to the triclinic system and, apparently, to the asymmetric group of that system. The pure compound melts at 107° . It does not dissolve in sodium carbonate, and gives no color with ferric chloride. It is extremely soluble in chloroform and benzene, very soluble in ether and acetone, readily in alcohol, and slightly in ligroin. Dilute sulphuric acid does not dissolve it, even in 50 per cent alcoholic solution. Analysis:

0.2125 gram substance gave 0.4624 gram CO_2 and 0.1045 gram H_2O .

	Calculated for $C_{20}H_{23}O_2N_2Br$.	Found.
C	59.52	59.35
H	5.75	5.50

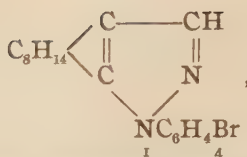
The substance is, therefore, *ethyl camphylparabromphenylpyrazolecarboxylate*,



which is formed from the addition compound by a condensation involving the loss of two molecules of water, and the formation of a pyrazole ring, esterification taking place also. The fact that it does not dissolve in acid shows that it is only very slightly basic, if at all. In contrast with this compound, ethyl camphylpyrazolecarboxylate forms a stable salt with hydrochloric acid (Cf. p. 15).

An attempt to prepare camphylpyrazolecarboxylic acid from camphylparabromphenylpyrazolecarboxylic acid, by oxidizing away the bromophenyl group, was not successful. The experiment was carried out with potassium permanganate, in boiling acetone solution, but the original substance was recovered unchanged.

What appears to be *camphylparabromphenylpyrazole* was obtained from the carboxylic acid by the action of heat. The acid fuses at 215° , and it was maintained at 215° – 218° until evolution of carbon dioxide ceased, which required about an hour for 3.5 grams. The cooled mass was vitreous, very lustrous and appeared black, but in small pieces it was only slightly brown, and was nearly transparent. It was found to be extremely soluble in all the ordinary organic solvents, including ligroin, and was left as an oily residue on spontaneous evaporation. On this account, I was unable to purify the small quantity of the substance which I had at my disposal and, therefore, no analysis was obtained. It is, without much doubt, camphylparabromphenylpyrazole,



because the analogous compound, camphylphenylpyrazole, is described by Bishop, Claisen and Sinclair¹ as having similar properties, and being very difficult to crystallize.

The Hydration Product of Camphoroxalic Acid.

Some years ago, Bishop Tingle² found that when camphoroxalic acid is heated with dilute, aqueous hydrochloric or sulphuric acid, a product is formed which gives an intense blue color with alcoholic ferric chloride solution, and has the composition of camphoroxalic acid plus 2 molecules of water. A further investigation of this substance was undertaken to determine, if possible, its structure, but on account of the extreme instability of the compound, the study has not yet been carried very far, but will, it is hoped, be taken up at a future date.

The substance was prepared as described by Bishop Tingle, by heating 6 grams of camphoroxalic acid with 25 cc. of 1 : 3 sulphuric acid, in a closed tube, at 135°–140°, for 9 to 10 hours. Variations in the concentration of the acid and in the temperature showed that the best results were obtained under the conditions described. The product had the horny appearance mentioned in the previous work, but crystals were observed only when the tubes were well filled, and the pressure, consequently, high. The yield was also improved by a high pressure. It appears to be best to fill the tubes nearly two-thirds full. The product has an aromatic odor, suggestive of fresh pine. It was purified by extracting in a Soxhlet apparatus with low-boiling ligroin, until the substance remaining in the extraction apparatus gives a pure blue color with alcoholic ferric chloride solution; this substance is then recrystallized from chloroform by the addition of ligroin. Temperatures above 60° must be avoided, as the compound reverts with the utmost readiness to camphoroxalic acid, therefore, the ligroin used for this extraction should

¹ Ann. Chem. (Liebig), **281**, 353.

² Am. Chem. J., **20**, 329 (1898).

boil below 60° , and solutions of the substance should not be warmed. It crystallizes, with difficulty, in nodular forms, which melt at 92° . The color reaction with ferric chloride is not instantaneous; first a yellow color appears, which changes gradually, through green, to a rich blue. Addition of water to the colored, alcoholic solution converts it to a bluish-violet. Analysis of the substance gave results agreeing with those obtained by Bishop Tingle.

The acid liquid from the tubes in which the reaction takes place contains some of the product, which can be recovered by extraction with ether. This liquid, before extraction with ether, has a strong odor like that of pine, as described above. When warmed, it gives up a small amount of carbon dioxide.

The hydration product yielded no salt when treated with barium chloride, but with barium hydroxide a salt was obtained which is readily soluble in water, fairly soluble in 50 per cent alcohol, but insoluble in absolute alcohol even on boiling. It was not analyzed. When the hydrated acid was treated carefully with aqueous sodium carbonate, of known strength, till litmus paper showed neutrality, 4 equivalents of the carbonate were required, indicating the tetrabascity of the acid. This was only an approximate determination.

When dissolved in chloroform, in the presence of 2 mols. of aniline, the substance yields, at the ordinary temperature, a compound melting at 158° , which is, apparently, identical with the product obtained under similar circumstances with camphoroxalic acid. The sodium salt, in aqueous solution, at room temperature, yields a compound with semicarbazine which melts at 200° and is identical with the substance obtained with camphoroxalic acid.

To an aqueous solution of the sodium salt there was added a solution of 2 molecules of hydroxylamine, obtained from the hydrochloride by the use of sodium carbonate; the mixture was allowed to remain for several days without heating. A colorless product is formed which is not precipitated by acidification, but can be extracted with ether. It melts, with decomposition, at 181° – 182° . No product of hydroxylamine

with camphoroxalic acid is known which has such a melting point. On account of the difficulty of preparing pure material in quantity, these investigations were not carried further.

THE COMBUSTION OF HALOGEN COMPOUNDS IN THE PRESENCE OF COPPER OXIDE.

In the course of the preceding investigation, occasion arose for determining carbon and hydrogen in certain compounds containing a halogen, and an attempt was made to do away with the necessity for preparing a combustion tube filled with lead chromate, by suitably modifying the ordinary tube containing copper oxide. This purpose was accomplished simply and satisfactorily in the following manner :

A cartridge, similar to that employed by Morse and Taylor¹ in the analysis of sulphur compounds, was made by rolling a small piece of heavy copper wire gauze into the form of a hollow cylinder just fitting into the combustion tube, filling this cylinder with pure lead chromate, and closing the ends by wrapping with copper wire. This also passed lengthwise through the cartridge, which was only 7 or 8 cm. long and was looped at each end to facilitate removal from the tube. The copper parts were oxidized by ignition. When it was desired to analyze halogen compounds, this cartridge was placed just in front of the boat, in a combustion tube filled in the ordinary way with copper oxide. In burning, care was taken that the part of the tube containing the cartridge was well heated before decomposition of the substance began, but no other special precautions were found necessary. If the space in the tube, or the decomposition temperature of the substance to be analyzed demand it, the oxidized spiral in front of the boat should, of course, be removed and the cartridge be allowed to occupy its place.

The advantages gained by the use of this method are that combustions of halogen compounds can be made just as readily as combustions of ordinary compounds, and that the same tube can be used for both. The cartridge may be removed or not, as the operator pleases, to make ordinary analyses subsequent

¹ Am. Chem. J., 33, 602.

to analyses of substances containing halogen. The same cartridge may be used repeatedly, but no statement can be made as to the number of times it can be employed safely without removal, because of the great variation in content of halogen in different compounds. The life of the tube itself is not affected as it is when the tube is entirely filled with lead chromate.

The method has been found to be so completely satisfactory that it is judged decidedly preferable, in very many cases, to determine carbon and hydrogen, rather than halogen, for the identification of new compounds. The time required for the analysis is much shorter, and the figures for the content of carbon and hydrogen in complex bodies are usually much more determinative than those for the content of halogen.

No special experiments have been conducted to test the method, but the analyses given below were made in the course of the investigation referred to (*vide* p. 65). The substances analyzed are products of the action of parabromphenylhydrazine on camphoroxalic acid. Only the one determination of carbon and hydrogen was made in each case.

I. A compound, $C_{18}H_{23}O_4N_2Br$, m. p. 149° , with decomposition.

0.2409 gram substance gave 0.4603 gram CO_2 and 0.1150 gram H_2O .

	Calculated.	Found.
C	52.53	52.14
H	5.63	5.34

II. A compound, $C_{18}H_{21}O_3N_2Br$, m. p. 172° , with decomposition.

0.2135 gram substance gave 0.4308 gram CO_2 and 0.0982 gram H_2O .

	Calculated.	Found.
C	54.94	55.03
H	5.38	5.15

III. A compound, $C_{20}H_{25}O_2N_2Br$, m. p. 107° .

0.2125 gram substance gave 0.4624 gram CO_2 and 0.1045 gram H_2O .

	Calculated	Found.
C	59.52	59.35
H	5.75	5.50

IV. A compound, $C_{18}H_{19}O_2N_2Br$, m. p. 215° , with decomposition.

0.1937 gram substance gave 0.4095 gram CO_2 and 0.0923 gram H_2O .

	Calculated.	Found.
C	57.58	57.66
H	5.10	5.33

The method has also been applied to the determination of nitrogen in halogen compounds. The cartridge of lead chromate is placed just in front of the substance to be burned and the latter is mixed with lead chromate. Otherwise the tube is filled in the ordinary way with copper oxide. The results obtained are shown in the following analysis :

The compound $C_{18}H_{21}O_3N_2Br$.

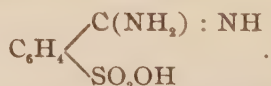
0.2624 gram substance gave 16.2 cc. N_2 at 19° and 758 mm.

	Calculated.	Found.
N	7.14	7.08

The determination of carbon and hydrogen in sulphur compounds could, doubtless, be accomplished in the same manner in the presence of copper oxide, but no experiments have been made in this direction.

SOME EXPERIMENTS RELATING TO THE SO-CALLED "INFUSIBLE DIAMIDE" OF PARASULPHAMINEBENZOIC ACID.

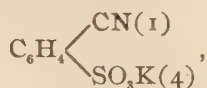
The so-called "infusible diamide," obtained by the action of heat on parasulphaminebenzoic acid, and investigated somewhat extensively by various workers¹ in this laboratory, was believed by Simmons, the last of those who worked on the problem, to be parasulphobenzamidine,



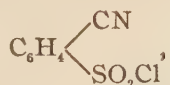
¹ The Dissertations of Hartman (1894), Muckenfuss (1895), Stoddard (1897), Chamberlain (1899), Simmons (1901). *Am. Chem. J.*, 18, 151 (1896).

Some evidence indicating this structure was collected, but it was not conclusive. At the suggestion of Professor Remsen the problem was taken up again in 1905, by the author, in the hope of obtaining further light on the subject, but for various reasons the investigation was discontinued after a short time, and has not since been resumed. Nevertheless, several observations were made which it seems desirable to place on record.

With the hope of obtaining the corresponding benzamidine derivative, potassium paracyanbenzenesulphonate,



was treated with absolute isobutyl alcohol and dry gaseous hydrochloric acid, according to the method of Pinner and Klein,¹ for making benzamidine compounds from nitriles. All precautions were taken to avoid contact with the moisture of the air, and the mixture was allowed to stand for a week. No reaction was observed to take place other than the liberation of paracyanbenzenesulphonic acid from its salt and the formation of potassium chloride. The potassium salt of this acid which was used in the experiment was prepared by Dr. C. E. Waters from paracyanbenzenesulphone chloride,



by warming it with water and adding occasionally small amounts of dilute potassium carbonate solution to neutralize the hydrochloric acid formed by hydrolysis of the chloride.

The "infusible diamide" was prepared and purified as described by Simmons.² Several unsuccessful attempts were made to methylate this substance with methyl iodide. Finally, the compound was placed in a closed tube with methyl iodide and methyl alcohol and heated at 100° for 50 hours. The product showed no signs of containing anything but the "infusible diamide" when extracted with various solvents, and crystallization from hot water appeared to give no other sub-

¹ Ber. d. chem. Ges., 10, 1889; 11, 4.

² Dissertation, p. 7.

stance. However, a part of the material from the tube was dissolved in aqueous potassium hydroxide and the solution distilled with steam, the distillate being received into hydrochloric acid solution which was subsequently evaporated to dryness. When the residue, after evaporation of the acid liquid, was washed with chloroform and the chloroform was evaporated, a very small amount of a solid was left which gave the odor of dimethylamine by treating with sodium hydroxide. The residue was then washed with absolute alcohol and the alcohol evaporated. A small amount of a white solid was left; it gave a yellow salt with platinum chloride and, when heated, charred, showing the presence of carbon; therefore the white residue was probably methylamine hydrochloride. Most of the residue consisted of ammonium chloride, consequently methylation had taken place to only a very slight extent. The methylated product, however, appeared to give both methylamine and dimethylamine when decomposed with alkali. The "infusible diamide" gives ammonia when so decomposed.

Attempts were made to prepare sulphonic acid salts of benzamidine, in order to see whether such substances might not have properties similar to those of the "infusible diamide." When silver benzenesulphonate and benzamidine hydrochloride are dissolved together in 95 per cent alcohol and warmed, silver chloride at once separates out, and the solution contains a substance which crystallizes with great readiness.

The crystals are usually rhombohedral in shape, but if crystallization takes place rapidly, they take the form of needles. The substance is fairly soluble in cold water and can be crystallized from aqueous solution. Boiling in water does not decompose it. Its melting-point is 174° .

Analysis :

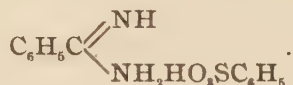
I. 0.2304 gram substance gave 0.4674 gram CO_2 and 0.1122 gram H_2O .

II. 0.2063 gram substance gave 17.8 cc. N_2 at 19° and 764 mm.

III. 0.2287 gram substance gave 0.1992 gram BaSO_4 (Liebig's method).

	Calculated for $C_{18}H_{14}O_3N_2S$.	Found.
C	56.07	55.33
H	5.07	5.44
N	10.08	9.97
S	11.52	11.96

From the method of synthesis, and from the analysis, there seems to be no doubt that the substance is *benzamidinebenzenesulphonate*,



So far as known, no sulphonic acid salts of benzamidine have hitherto been described.

When silver paratoluenesulphonate and benzamidine hydrochloride are dissolved together in alcohol, silver chloride is precipitated and the solution yields colorless, flattened prisms, apparently belonging to the orthorhombic system. This substance melts at a very high temperature, above 310° . No residue is left on incineration. The compound was not further studied.

No other results of significance were obtained in this brief and incomplete investigation.

BIOGRAPHICAL.

Charles J. Robinson was born near Goodfield, Woodford County, Illinois, on December 12, 1882. In 1891, he moved with his parents to Bloomington, Illinois, and his preparation for college was received in the High School of that place and in the Preparatory School of Illinois Wesleyan University. He entered upon the college course in the latter institution in September, 1899, and received the degree of Bachelor of Science in June, 1903. Since then he has been enrolled in the Johns Hopkins University as a graduate student in chemistry, his subordinate subjects being physical chemistry and mineralogy.

